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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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C09K 19/30	(2006.01)
C09K 19/44	(2006.01)
C09K 19/12	(2006.01)
G02F 1/1337	(2006.01)

(52) **U.S. Cl.**

CPC ***C09K 19/322*** (2013.01); ***C09K 19/3003*** (2013.01); ***C09K 19/3066*** (2013.01); ***C09K19/44*** (2013.01); ***G02F 1/133512*** (2013.01); ***G02F 1/133514*** (2013.01); *C09K 2019/123* (2013.01); *C09K 2019/301* (2013.01); *C09K 2019/3004* (2013.01); *C09K 2019/3009* (2013.01); *C09K 2019/3016* (2013.01); *C09K 2019/3027* (2013.01); *G02F 2001/133742* (2013.01)

(58) **Field of Classification Search**

USPC 349/96

See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

(57) **ABSTRACT**

There is provided a liquid crystal display device which prevents a decrease in the voltage holding ratio (VHR) of a liquid crystal layer and an increase in ion density (ID) therein and which overcomes problems of defective display such as voids, uneven alignment, and screen burn-in. The liquid crystal display device prevents a decrease in the voltage holding ratio (VHR) of a liquid crystal layer and an increase in ion density (ID) therein and reduces defective display such as screen burn-in; hence, such a liquid crystal display device is particularly useful as liquid crystal display devices of a VA mode and PSVA mode which involve active matrix driving and can be applied to the liquid crystal display devices of liquid crystal TV sets, monitors, mobile phones, and smartphones.

16 Claims, 2 Drawing Sheets

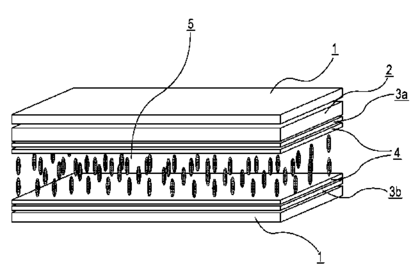


FIG. 1

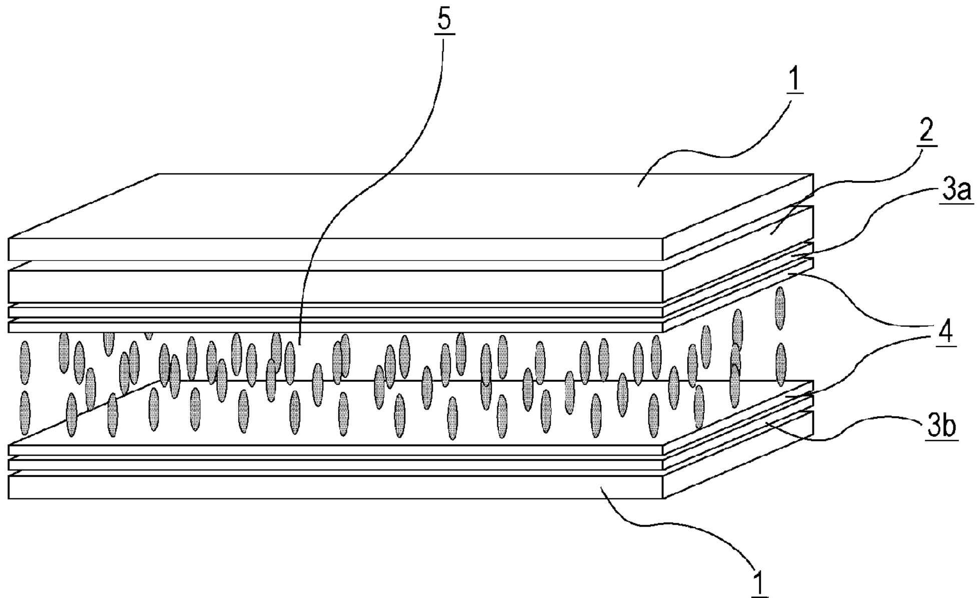


FIG. 2

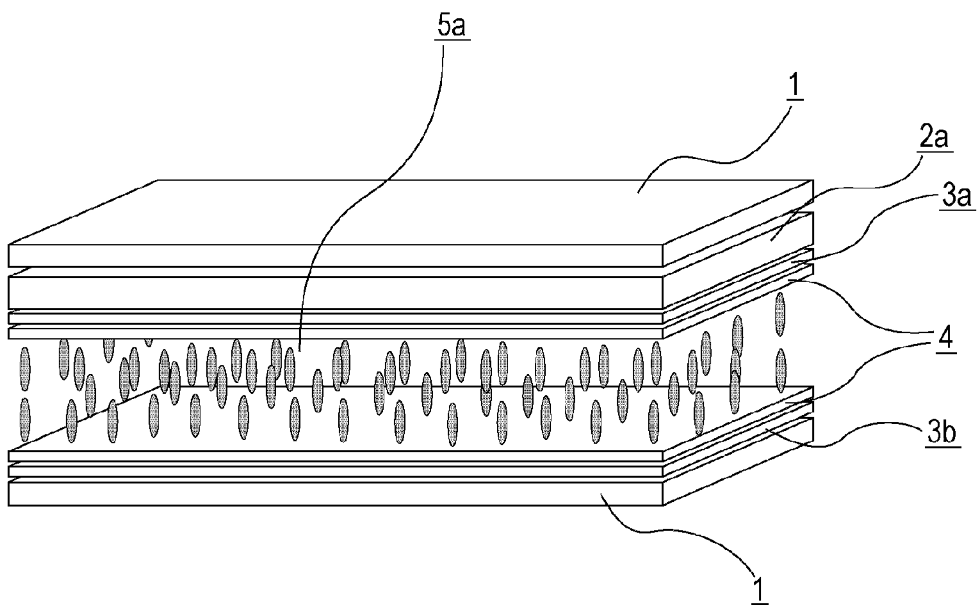
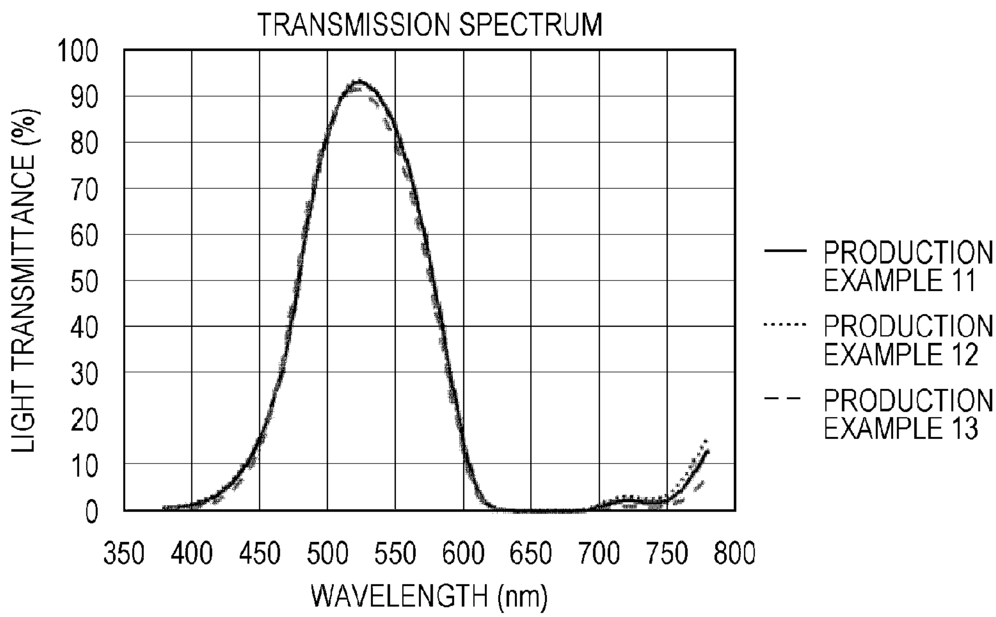


FIG. 3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60
50
40
30
20
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WAVELENGTH (nm)
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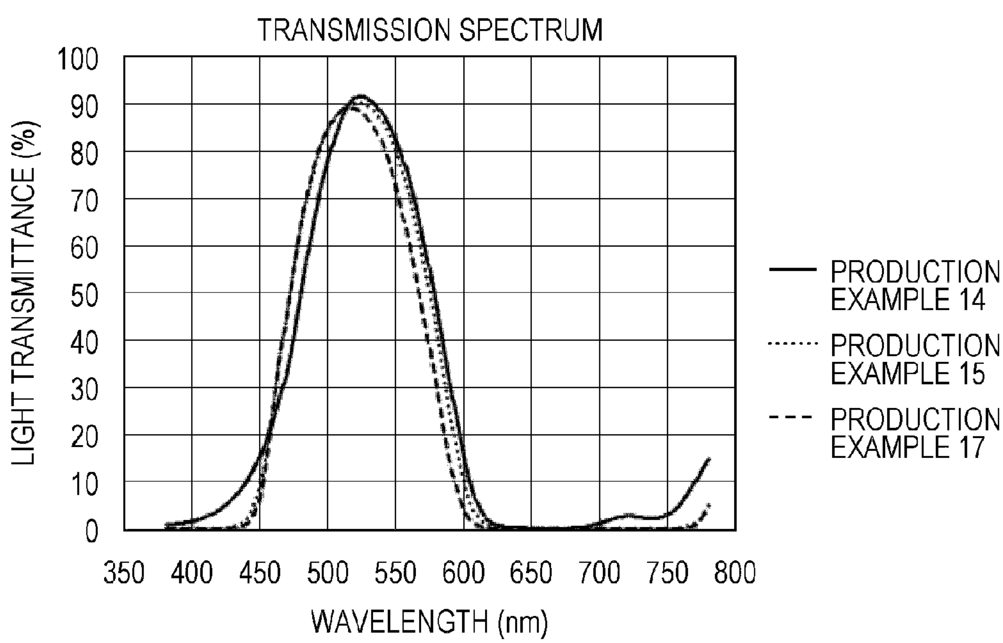
PRODUCTION EXAMPLE 12
PRODUCTION EXAMPLE 13

FIG. 4


TRANSMISSION SPECTRUM
LIGHT TRANSMITTANCE (%)
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40
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WAVELENGTH (nm)
PRODUCTION EXAMPLE 14
PRODUCTION EXAMPLE 15
PRODUCTION EXAMPLE 17

LIQUID CRYSTAL DISPLAY DEVICE

TECHNICAL FIELD

The present invention relates to a liquid crystal display device.

BACKGROUND ART

Liquid crystal display devices have been applied to, for example, watches, calculators, a variety of household electrical appliances, measuring equipment, panels used in automobiles, word processors, electronic notebooks, printers, computers, and television sets. Representative examples of types of liquid crystal display devices include a TN (twisted nematic) type, an STN (super twisted nematic) type, a DS (dynamic scattering) type, a GH (guest-host) type, an IPS (in-plane switching) type, an OCB (optically compensated birefringence) type, an ECB (electrically controlled birefringence) type, a VA (vertical alignment) type, a CSH (color super homeotropic) type, and an FLC (ferroelectric liquid crystal) type. Regarding a drive system, multiplex driving has become popular instead of typical static driving; and an active matrix (AM) in which, for example, a TFT (thin film transistor) or a TFD (thin film diode) is used for driving has become standard rather than a passive matrix in recent years.

As illustrated in FIG. **1**, in a general color liquid crystal display device, a transparent electrode layer (**3***a*) as a common electrode and a color filter layer (**2**) are disposed between one of two substrates (**1**) and one of alignment films (**4**) provided so as to correspond thereto, a pixel electrode layer (**3***b*) is disposed between the other substrate and the other alignment film, the substrates are disposed such that the alignment films face each other, and a liquid crystal layer (**5**) is disposed therebetween.

The color filter layer is a color filter consisting of a black matrix, a red layer (R), a green layer (G), a blue layer (B), and optionally a yellow layer (Y).

Impurities remaining in liquid crystal materials used in a liquid crystal layer have a large effect on the electrical properties of a display device, and the impurities have been therefore highly controlled. In terms of materials used in alignment films, it has been known that impurities remaining in the alignment films directly contacting a liquid crystal layer shift to the liquid crystal layer with the result that the impurities affect the electrical properties of the liquid crystal layer; hence, the relationship between the properties of liquid crystal display devices and impurities contained in the materials of alignment films have been being studied.

Also in terms of materials used in a color filter layer, such as organic pigments, it is believed that impurities contained therein have an effect on a liquid crystal layer as in the materials of alignment films. However, since an alignment film and a transparent electrode are disposed between the color filter layer and the liquid crystal layer, it has been believed that direct effect thereof on the liquid crystal layer is significantly smaller than that of the materials of the alignment film. In general, however, the thickness of the alignment film is only not more than 0.1 μm, and the thickness of the transparent electrode that is a common electrode disposed on the color filter layer side is not more than 0.5 μm even in the case where the thickness is increased to enhance the electric conductivity. Hence, the color filter layer and the liquid crystal layer are not in a state in which they are completely isolated from each other, and the color filter layer may therefore cause problems owing to impurities which are contained in the color filter layer and which

pass through the alignment film and the transparent electrode, such as a decrease in the voltage holding ratio (VHR) of the liquid crystal layer and defective display including voids due to increased ion density (ID), uneven alignment, and screen burn-in.

Techniques for overcoming defective display caused by impurities present in a pigment contained in the color filter layer have been studied, such as a technique in which dissolution of impurities in liquid crystal is controlled by use of a pigment in which the amount of an extract from the pigment by ethyl formate is at a predetermined level or lower (Patent Literature 1) and a technique in which dissolution of impurities in liquid crystal is controlled by use of a specific pigment for a blue layer (Patent Literature 2). These techniques, however, are substantially not different from merely reducing the impurity content in a pigment and are insufficient in improvements to overcome defective display even in a current situation in which a technique for purifying pigments has been advanced.

In another disclosed technique, attention is paid to the relationship between organic impurities contained in a color filter layer and a liquid crystal composition, the degree in which the organic impurities are less likely to be dissolved in a liquid crystal layer is represented by the hydrophobic parameter of liquid crystal molecules contained in the liquid crystal layer, and the hydrophobic parameter is adjusted to be at a predetermined level or more; furthermore, since such a hydrophobic parameter has a correlation with a $—OCF_3$ group present at an end of a liquid crystal molecule, a liquid crystal composition is prepared so as to contain a predetermined amount or more of a liquid crystal compound having a $—OCF_3$ group at an end of each liquid crystal molecule thereof (Patent Literature 3).

Also in such disclosure, however, the technique is substantially for reducing effects of impurities present in a pigment on the liquid crystal layer, and a direct relationship between the properties of a colorant itself used in the color filter layer, such as a dye or a pigment, and the structure of a liquid crystal material is not considered; thus, problems of defective display in highly-developed liquid crystal display devices have not been overcome.

CITATION LIST

Patent Literature

PTL 1: Japanese Unexamined Patent Application Publication No. 2000-19321

PTL 2: Japanese Unexamined Patent Application Publication No. 2009-109542

PTL 3: Japanese Unexamined Patent Application Publication No. 2000-192040

SUMMARY OF INVENTION

Technical Problem

It is an object of the present invention to provide a liquid crystal display device in which a specific liquid crystal composition and a color filter containing an organic pigment having a specific particle size distribution are used to prevent a decrease in the voltage holding ratio (VHR) of a liquid crystal layer and an increase in ion density (ID) therein and to overcome problems of defective display such as voids, uneven alignment, and screen burn-in.

Solution to Problem

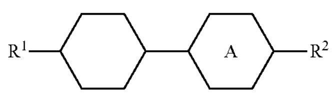
In order to achieve the above-mentioned object, the inventors have intensively studied a structural combination of a color filter containing an organic colorant and a liquid crystal material used for forming a liquid crystal layer and found that a liquid crystal display device in which a specific liquid crystal material and a color filter containing an organic pigment having a specific particle size distribution are used prevents a decrease in the voltage holding ratio (VHR) of the liquid crystal layer and an increase in ion density (ID) therein and eliminates problems of defective display such as voids, uneven alignment, and screen burn-in, thereby accomplishing the present invention.

In particular, the present invention provides a liquid crystal display device including a first substrate, a second substrate, a liquid crystal composition layer disposed between the first substrate and the second substrate, a color filter including a black matrix and at least RGB three-color pixels, a pixel electrode, and a common electrode, wherein

the liquid crystal composition layer contains a liquid crystal composition containing a compound represented by General Formula (I) in an amount of 30 to 50%

[Chem. 1]

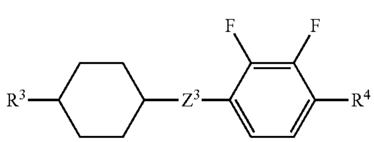
(I)



(where R^1 and R^2 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; and A represents a 1,4-phenylene group or a trans-1,4-cyclohexylene group), a compound represented by General Formula (II-1) in an amount of 5 to 30%

[Chem. 2]

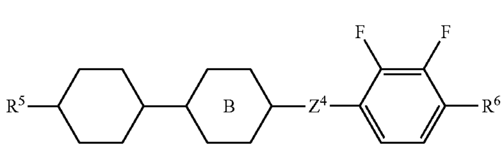
(II-1)



(where R^3 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^4 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; and Z^3 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—), and a compound represented by General Formula (II-2) in an amount of 25 to 45%

[Chem. 3]

(II-2)



(where R^5 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^6 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; B represents a 1,4-phenylene group or trans-1,4-cyclohexylene group which is optionally substituted with a fluorine atom; and Z^4 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—); and the color filter contains an organic pigment, wherein among the whole particles of the organic pigment, particles having a particle size greater than 1000 nm have a volume fraction of not more than 1%, and particles having a particle size ranging from 40 nm to 1000 nm have a volume fraction of not more than 25%.

Advantageous Effects of Invention

In the liquid crystal display device of the present invention, using a specific liquid crystal composition and a color filter containing an organic pigment having a specific particle size distribution enables prevention of a decrease in the voltage holding ratio (VHR) of a liquid crystal layer, prevention of an increase in ion density (ID) therein, and elimination of defective display such as voids, uneven alignment, and screen burn-in.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates an example of typical liquid crystal display devices generally used.

FIG. **2** illustrates an example of the liquid crystal display device of the present invention.

FIG. **3** illustrates the transmission spectra in color filters.

FIG. **4** illustrates the transmission spectra in color filters.

REFERENCE SIGNS LIST

1 Substrate
2 Color filter layer
2*a* Color filter layer containing organic pigment having specific particle size distribution
3*a* Transparent electrode layer (common electrode)
3*b* Pixel electrode layer
4 Alignment film
5 Liquid crystal layer
5*a* Liquid crystal layer containing specific liquid crystal composition

DESCRIPTION OF EMBODIMENTS

FIG. **2** illustrates an example of the liquid crystal display device of the present invention. In the liquid crystal display device, a transparent electrode layer (**3*a***) as a common electrode and a color filter layer (**2*a***) containing an organic pigment having a specific particle size distribution are disposed between one of two substrates (**1**) of first and second substrates and one of alignment films (**4**) provided so as to correspond thereto, a pixel electrode layer (**3*b***) is disposed between the other substrate and the other alignment film, the substrates are disposed such that the alignment films face each other, and a liquid crystal layer (**5*a***) containing a specific liquid crystal composition is disposed therebetween.

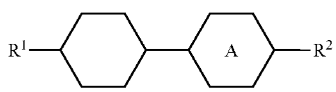
In the display device, the two substrates are attached to each other with a sealant and sealing material placed at the peripheries thereof, and particulate spacers or spacer columns formed of resin by photolithography are disposed between the substrates to maintain the distance therebetween in many cases.

(Liquid Crystal Layer)

The liquid crystal layer of the liquid crystal display device of the present invention is composed of a liquid crystal composition containing a compound represented by General Formula (I) in an amount of 30 to 50%

[Chem. 4]

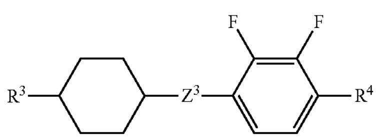
(I)



(where R^1 and R^2 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; and A represents a 1,4-phenylene group or a trans-1,4-cyclohexylene group), a compound represented by General Formula (II-1) in an amount of 5 to 30%

[Chem. 5]

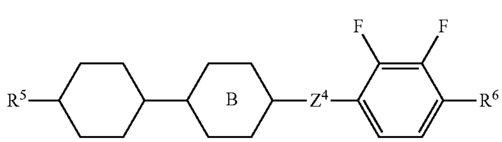
(II-1)



(where R^3 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^4 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; and Z^3 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—), and a compound represented by General Formula (II-2) in an amount of 25 to 45%

[Chem. 6]

(II-2)



(where R^5 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^6 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; B represents a 1,4-phenylene group or trans-1,4-cyclohexylene group which is optionally substituted with a fluorine atom; and Z^4 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—).

The amount of the compound represented by General Formula (I) in the liquid crystal layer of the liquid crystal display device of the present invention is from 30 to 50%, preferably 32 to 48%, and more preferably 34 to 46%.

In General Formula (I), R^1 and R^2 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; in the case where A is a trans-1,4-cyclohexylene group,

R^1 and R^2 preferably each independently represent an alkyl group having 1 to 5 carbon atoms, an alkenyl group having 2 to 5 carbon atoms, an alkoxy group having 1 to 5 carbon atoms, or an alkenyloxy group having 2 to 5 carbon atoms; and

more preferably an alkyl group having 2 to 5 carbon atoms, an alkenyl group having 2 to 4 carbon atoms, an alkoxy group having 1 to 4 carbon atoms, or an alkenyloxy group having 2 to 4 carbon atoms.

R^1 preferably represents an alkyl group; in this case, an alkyl group having 2, 3, or 4 carbon atoms is especially preferred. In the case where R^1 represents an alkyl group having 3 carbon atoms, R^2 is preferably an alkyl group having 2, 4, or 5 carbon atoms or an alkenyl group having 2 or 3 carbon atoms, and more preferably an alkyl group having 2 carbon atoms.

In the case where A represents a 1,4-phenylene group, R^1 and R^2 preferably each independently represent an alkyl group having 1 to 5 carbon atoms, an alkenyl group having 4 or 5 carbon atoms, an alkoxy group having 1 to 5 carbon atoms, or an alkenyloxy group having 3 to 5 carbon atoms; and

more preferably an alkyl group having 2 to 5 carbon atoms, an alkenyl group having 4 or 5 carbon atoms, an alkoxy group having 1 to 4 carbon atoms, or an alkenyloxy group having 2 to 4 carbon atoms.

R^1 preferably represents an alkyl group; in this case, an alkyl group having 1, 3, or 5 carbon atoms is especially preferred. In addition, R^2 preferably represents an alkoxy group having 1 or 2 carbon atoms.

The amount of a compound represented by General Formula (I) in which at least one of the substituents R^1 and R^2 is an alkyl group having 3 to 5 carbon atoms preferably accounts for not less than 50%, more preferably not less than 70%, and further preferably not less than 80% of the total amount of compounds represented by General Formula (I). Moreover, the amount of a compound represented by General Formula (I) in which at least one of the substituents R^1 and R^2 is an alkyl group having 3 carbon atoms preferably accounts for not less than 50%, more preferably not less than 70%, further preferably not less than 80%, and most preferably 100% of the total amount of compounds represented by General Formula (I).

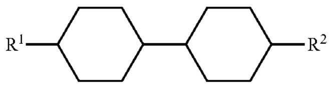
One or more compounds represented by General Formula (I) can be used, and at least one compound in which A represents a trans-1,4-cyclohexylene group and at least one compound in which A represents a 1,4-phenylene group are preferably used.

The amount of a compound represented by General Formula (I) in which A represents a trans-1,4-cyclohexylene group preferably accounts for not less than 50%, more preferably not less than 70%, and further preferably not less than 80% of the total amount of compounds represented by General Formula (I).

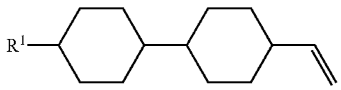
In particular, the compound represented by General Formula (I) is preferably any of the following compounds represented by General Formulae (Ia) to (Ik).

[Chem. 7]

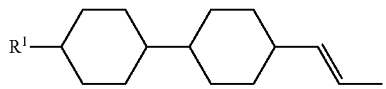
(Ia)



(Ib)



(Ic)



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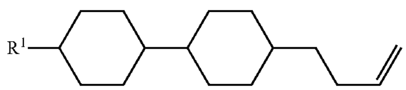
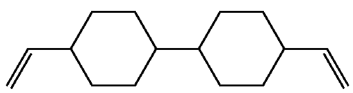


(Ie)



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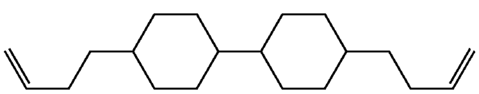
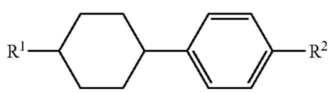


(Ig)



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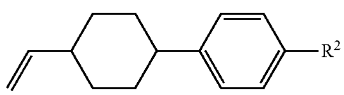
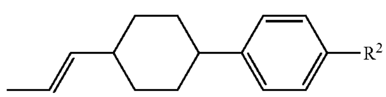
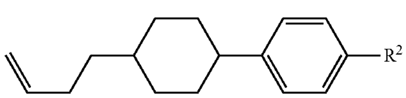


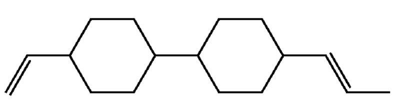
(Ii)



(Ij)



(Ik)



(where R^1 and R^2 each independently represent an alkyl group having 1 to 5 carbon atoms or an alkoxy group having 1 to 5 carbon atoms and preferably have the same meanings as R^1 and R^2 in General Formula (I), respectively) Among General Formulae (Ia) to (Ik), General Formulae (Ia), (Ic), and (Ig) are preferred; General Formulae (Ia) and (Ig) are more preferred; and General Formula (Ia) is especially preferred. In the case of focusing on a response speed, General Formula (Ib) is also preferred; in the case of further focusing on a response speed, General Formulae (Ib), (Ic), (Ie), and (Ik) are preferred, and General Formulae (Ic) and (Ik) are more preferred. Dialkenyl compounds represented by General Formula (Ik) are preferred in the case of especially focusing on a response speed.

From this viewpoint, the amount of compounds represented by General Formulae (Ia) and (Ic) is preferably not less than 50%, more preferably not less than 70%, further preferably not less than 80%, and most preferably 100% relative to the total amount of compounds represented by General Formula (I). The amount of a compound represented by General Formula (Ia) is preferably not less than 50%, more preferably not less than 70%, and further preferably not less than 80% relative to the total amount of compounds represented by General Formula (I).

The amount of the compound represented by General Formula (II-1) in the liquid crystal layer of the liquid crystal display device of the present invention is from 5 to 30%, preferably 8 to 27%, and more preferably 10 to 25%. In General Formula (II-1), R^3 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; preferably an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms; more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 2 to 4 carbon atoms; further preferably an alkyl group having 3 to 5 carbon atoms or an alkenyl group having 2 carbon atoms; and especially preferably an alkyl group having 3 carbon atoms.

R^4 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; preferably an alkyl group having 1 to 5 carbon atoms or an alkoxy group having 1 to 5 carbon atoms; more preferably an alkyl group having 1 to 3 carbon atoms or an alkoxy group having 1 to 3 carbon atoms; further preferably an alkyl group having 3 carbon atoms or an alkoxy group having 2 carbon atoms; and especially preferably an alkoxy group having 2 carbon atoms.

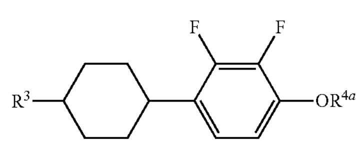
Z^3 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—; preferably a single bond, —CH_2CH_2—, —COO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—; and more preferably a single bond or —CH_2O—.

The liquid crystal layer of the liquid crystal display device of the present invention can contain at least one compound represented by General Formula (II-1) and preferably contains one or two compounds represented by General Formula (II-1).

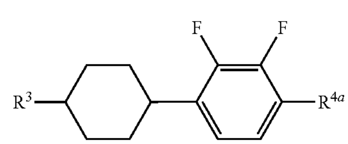
In particular, the compound represented by General Formula (II-1) is preferably any of compounds represented by General Formulae (II-1a) to (II-1d).

[Chem. 8]

(II-1a)

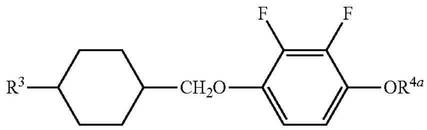


(II-1b)

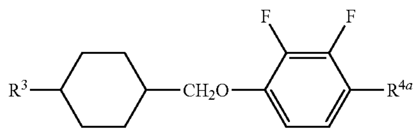


-continued

(II-1c)



(II-1d)



(where R^3 represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms; and R^{4a} represents an alkyl group having 1 to 5 carbon atoms)

In General Formulae (II-1a) and (II-1c), R^3 preferably has the same meaning as R^3 in General Formula (II-1). R^{4a} preferably represents an alkyl group having 1 to 3 carbon atoms, more preferably an alkyl group having 1 or 2 carbon atoms, and especially preferably an alkyl group having 2 carbon atoms.

In General Formulae (II-1b) and (II-1d), R^3 preferably has the same meaning as R^3 in General Formula (II-1). R^{4a} preferably represents an alkyl group having 1 to 3 carbon atoms, more preferably an alkyl group having 1 or 3 carbon atoms, and especially preferably an alkyl group having 3 carbon atoms.

Among General Formulae (II-1a) to (II-1d), in order to increase the absolute value of dielectric anisotropy, General Formulae (II-1a) and (II-1c) are preferred, and General Formula (II-1a) is more preferred.

The liquid crystal layer of the liquid crystal display device of the present invention preferably contains at least one of compounds represented by General Formulae (II-1a) to (II-1d), also preferably one or two of them, and also preferably one or two of compounds represented by General Formula (II-1a).

The amount of the compound represented by General Formula (II-2) in the liquid crystal layer of the liquid crystal display device of the present invention is from 25 to 45%, preferably 28 to 42%, and more preferably 30 to 40%.

In General Formula (II-2), R^5 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; preferably an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms; more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 2 to 4 carbon atoms; further preferably an alkyl group having 3 to 5 carbon atoms or an alkenyl group having 2 carbon atoms; and especially preferably an alkyl group having 3 carbon atoms.

R^6 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; preferably an alkyl group having 1 to 5 carbon atoms or an alkoxy group having 1 to 5 carbon atoms; more preferably an alkyl group having 1 to 3 carbon atoms or an alkoxy group having 1 to 3 carbon atoms; further preferably an alkyl group having 3 carbon atoms or an alkoxy group having 2 carbon atoms; and especially preferably an alkoxy group having 2 carbon atoms.

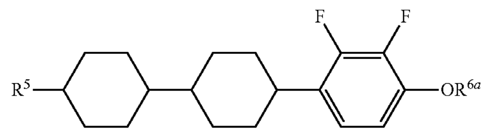
B represents a 1,4-phenylene group or trans-1,4-cyclohexylene group which is optionally substituted with a fluorine atom, preferably an unsubstituted 1,4-phenylene group or trans-1,4-cyclohexylene group, and more preferably the trans-1,4-cyclohexylene group.

Z^4 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—; preferably a single bond, —CH_2CH_2—, —COO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—; and more preferably a single bond or —CH_2O—.

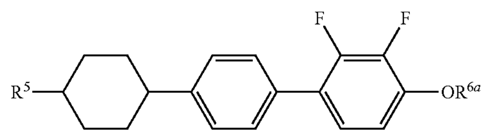
In particular, the compound represented by General Formula (II-2) is preferably any of compounds represented by General Formulae (II-2a) to (II-2f).

[Chem. 9]

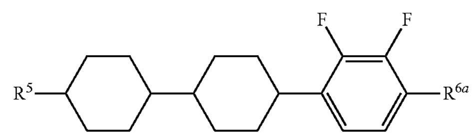
(II-2a)



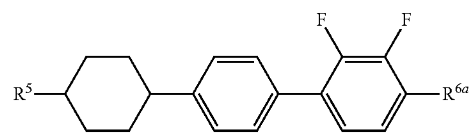
(II-2b)



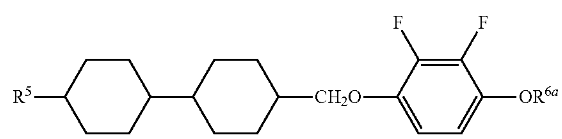
(II-2c)



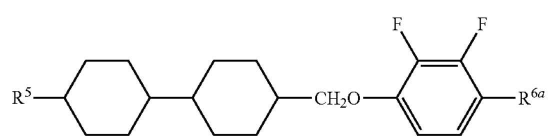
(II-2d)



(II-2e)



(II-2f)



(where R^5 represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms, and R^{6a} represents an alkyl group having 1 to 5 carbon atoms; R^5 and R^{6a} preferably have the same meanings as R^5 and R^6 in General Formula (II-2), respectively)

In General Formulae (II-2a), (II-2b), and (II-2e), R^5 preferably has the same meaning as R^5 in General Formula (II-2). R^{6a} is preferably an alkyl group having 1 to 3 carbon atoms, more preferably an alkyl group having 1 or 2 carbon atoms, and especially preferably an alkyl group having 2 carbon atoms.

In General Formulae (II-2c), (II-2d), and (II-2f), R^5 preferably has the same meaning as R^5 in General Formula (II-2). R^{6a} is preferably an alkyl group having 1 to 3 carbon atoms, more preferably an alkyl group having 1 or 3 carbon atoms, and especially preferably an alkyl group having 3 carbon atoms.

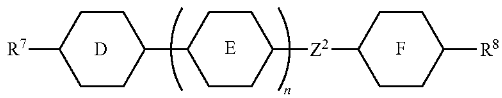
Among General Formulae (II-2a) to (II-2f), in order to increase the absolute value of dielectric anisotropy, General Formulae (II-2a), (II-2b), and (II-2e) are preferred.

One or more compounds represented by General Formula (II-2) can be used; it is preferred that at least one compound in which B represents a 1,4-phenylene group and at least one compound in which B represents a trans-1,4-cyclohexylene group be used.

The liquid crystal layer of the liquid crystal display device of the present invention preferably further contains a compound represented by General Formula (III).

[Chem. 10]

(III)



(where R^7 and R^8 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; D, E, and F each independently represent a 1,4-phenylene group or trans-1,4-cyclohexylene which is optionally substituted with a fluorine atom; Z^2 represents a single bond, —OCH_2—, —OCO—, —CH_2O—, —COO—, or —OCO—; n represents 0, 1, or 2; and the compound represented by General Formula (III) excludes the compounds represented by General Formulae (I), (II-1), and (II-2).

The amount of the compound represented by General Formula (III) is preferably in the range of 3 to 35%, more preferably 5 to 33%, and further preferably 7 to 30%.

In General Formula (III), R^7 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms. In the case where D represents trans-1,4-cyclohexylene, R^7 preferably represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms, more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 2 to 4 carbon atoms, further preferably an alkyl group having 3 to 5 carbon atoms or an alkenyl group having 2 or 3 carbon atoms, and especially preferably an alkyl group having 3 carbon atoms.

In the case where D represents a 1,4-phenylene group which is optionally substituted with a fluorine atom, R^7 preferably represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 4 or 5 carbon atoms, more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 4 carbon atoms, and further preferably an alkyl group having 2 to 4 carbon atoms.

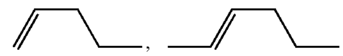
R^8 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms.

In the case where F represents trans-1,4-cyclohexylene, R^8 preferably represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms, more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 2 to 4 carbon atoms, further preferably an alkyl group having 3 to 5 carbon atoms or an alkenyl group having 2 or 3 carbon atoms, and especially preferably an alkyl group having 3 carbon atoms.

In the case where F represents a 1,4-phenylene group which is optionally substituted with a fluorine atom, R^8 preferably represents an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 4 or 5 carbon atoms, more preferably an alkyl group having 2 to 5 carbon atoms or an alkenyl group having 4 carbon atoms, and further preferably an alkyl group having 2 to 4 carbon atoms.

In the case where R^7 and R^8 each represent an alkenyl group and where any one of D and F bonded to R^7 and R^8, respectively, is a 1,4-phenylene group which is optionally substituted with a fluorine atom, an alkenyl group having 4 or 5 carbon atoms is preferably any of the following structures.

[Chem. 11]



(where the right end of each of the structures is bonded to the ring structure)

Also in this case, an alkenyl group having 4 carbon atoms is more preferred.

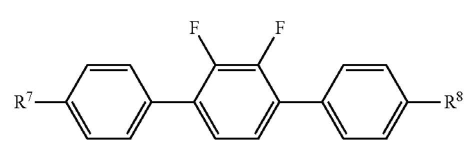
D, E, and F each independently represent a 1,4-phenylene group or trans-1,4-cyclohexylene which is optionally substituted with a fluorine atom; preferably a 2-fluoro-1,4-phenylene group, a 2,3-difluoro-1,4-phenylene group, a 1,4-phenylene group, or trans-1,4-cyhclohexylene; more preferably a 2-fluoro-1,4-phenylene group, a 2,3-difluoro-1,4-phenylene group, or a 1,4-phenylene group; especially preferably a 2,3-difluoro-1,4-phenylene group or a 1,4-phenylene group.

Z^2 represents a single bond, —OCH_2—, —OCO—, —CH_2O—, or —COO—; preferably a single bond, —CH_2O—, or —COO—; and more preferably a single bond.

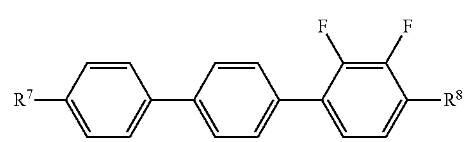
n represents 0, 1, or 2; and preferably 0 or 1. In the case where Z^2 does not represent a single bond but represents a substituent, n preferably represents 1. In the case where n represents 1, the compound represented by General Formula (III) is preferably any of compounds represented by General Formulae (III-1a) to (III-1e) in terms of an enhancement in negative dielectric anisotropy or any of compounds represented by General Formulae (III-1f) to (III-1j) in terms of an increase in a response speed.

[Chem. 12]

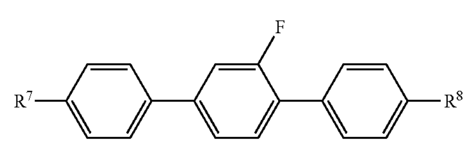
(III-1a)



(III-1b)



(III-1c)



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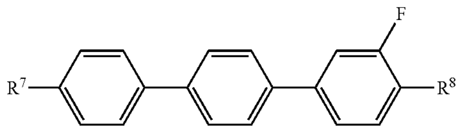
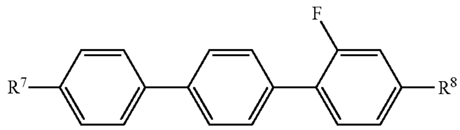
(III-1d)

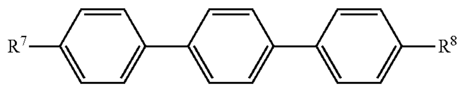


(III-1e)

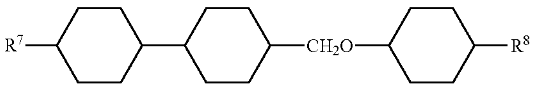


[Chem. 13]

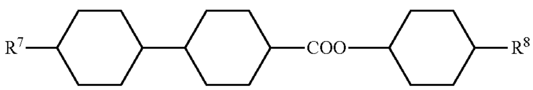
(III-1f)



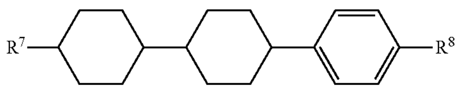
(III-1g)



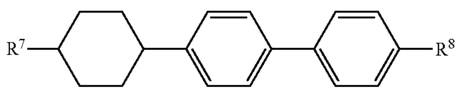
(III-1h)



(III-1i)



(III-1j)

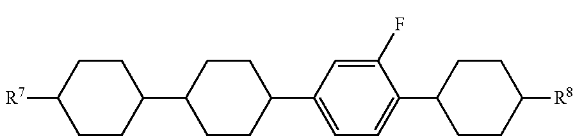


(where R^7 and R^8 each independently represent an alkyl group having 1 to 5 carbon atoms, an alkenyl group having 2 to 5 carbon atoms, or an alkoxy group having 1 to 5 carbon atoms; R^7 and R^8 preferably have the same meanings as R^7 and R^8 in General Formula (III), respectively)

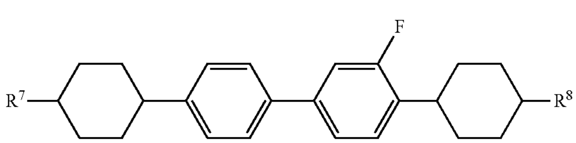
In the case where n represents 2, the compound represented by General Formula (III) is preferably any of compounds represented by General Formulae (III-2a) to (III-2i) in terms of an enhancement in negative dielectric anisotropy or any of compounds represented by General Formulae (III-2j) to (III-21) in terms of an increase in a response speed.

[Chem. 14]

(III-2a)



(III-2b)



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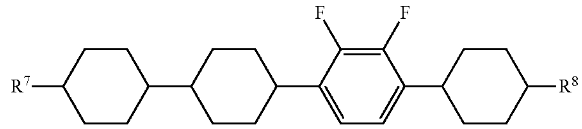
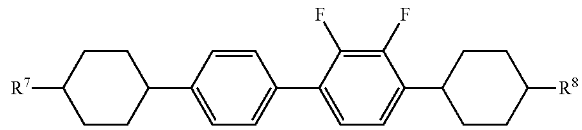
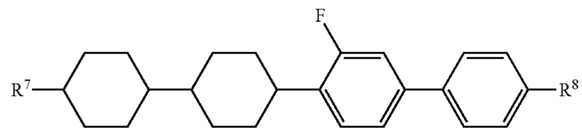
(III-2c)



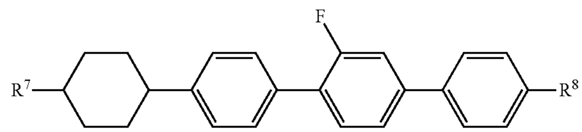
(III-2d)



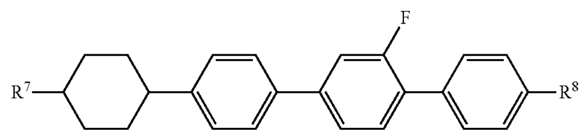
(III-2e)



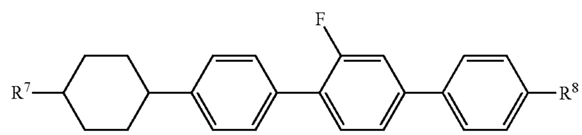
(III-2f)



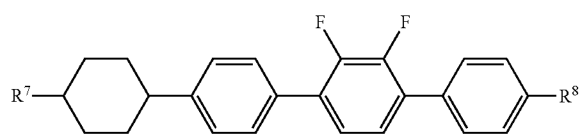
(III-2g)



(III-2h)

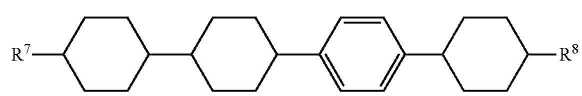


(III-2i)

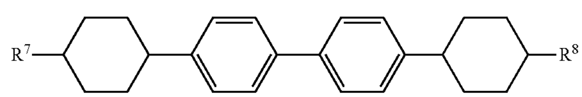


[Chem. 15]

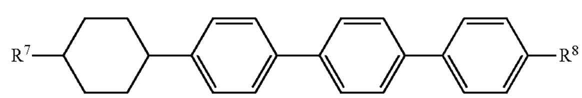
(III-2j)



(III-2k)



(III-2l)

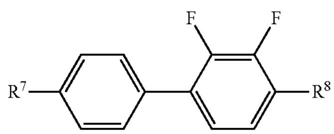


(where R^7 and R^8 each independently represent an alkyl group having 1 to 5 carbon atoms, an alkenyl group having 2 to 5 carbon atoms, or an alkoxy group having 1 to 5 carbon atoms; R^7 and R^8 preferably have the same meanings as R^7 and R^8 in General Formula (III), respectively)

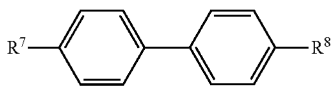
In the case where n represents 0, the compound represented by General Formula (III) is preferably a compound represented by General Formula (III-3a) in terms of an enhancement in negative dielectric anisotropy or a compound represented by General Formula (III-3b) in terms of an increase in a response speed.

[Chem. 16]

(III-3a)



(III-3b)



(where R^7 and R^8 each independently represent an alkyl group having 1 to 5 carbon atoms, an alkenyl group having 2 to 5 carbon atoms, or an alkoxy group having 1 to 5 carbon atoms; R^7 and R^8 preferably have the same meanings as R^7 and R^8 in General Formula (III), respectively)

R^7 preferably represents an alkyl group having 2 to 5 carbon atoms, and more preferably an alkyl group having 3 carbon atoms. R^8 preferably represents an alkoxy group having 1 to 3 carbon atoms, and more preferably an alkoxy group having 2 carbon atoms.

Each of the compounds represented by General Formulae (II-1) and (II-2) is a compound having a negative dielectric anisotropy with a relatively large absolute value; the total amount thereof is preferably in the range of 30 to 65%, more preferably 40 to 55%, and especially preferably 43 to 50%.

The compound represented by General Formula (III) includes a compound having a positive dielectric anisotropy and a compound having a negative dielectric anisotropy. In the case where a compound represented by General Formula (III) and having a negative dielectric anisotropy with an absolute value of not less than 0.3 is used, the total amount of compounds represented by General Formulae (II-1), (II-2), and (III) is preferably in the range of 35 to 70%, more preferably 45 to 65%, and especially preferably 50 to 60%.

It is preferred that the amount of the compound represented by General Formula (I) be in the range of 30 to 50% and that the amount of the compounds represented by General Formulae (II-1), (II-2), and (III) be in the range of 35 to 70%; it is more preferred that the amount of the compound represented by General Formula (I) be in the range of 35 to 45% and that the amount of the compounds represented by General Formulae (II-1), (II-2), and (III) be in the range of 45 to 65%; and it is especially preferred that the amount of the compound represented by General Formula (I) be in the range of 38 to 42% and that the amount of the compounds represented by General Formulae (II-1), (II-2), and (III) be in the range of 50 to 60%.

The total amount of the compounds represented by General Formulae (I), (II-1), (II-2), and (III) is preferably in the range of 80 to 100%, more preferably 90 to 100%, and especially preferably 95 to 100% relative to the total amount of the composition.

The liquid crystal layer of the liquid crystal display device of the present invention can be used in a wide range of nematic phase-isotropic liquid phase transition temperature (T_{ni}); this temperature range is preferably from 60 to 120° C., more preferably from 70 to 100° C., and especially preferably from 70 to 85° C.

The dielectric anisotropy is preferably in the range of −2.0 to −6.0, more preferably −2.5 to −5.0, and especially preferably −2.5 to −4.0 at 25° C.

The refractive index anisotropy is preferably from 0.08 to 0.13, and more preferably from 0.09 to 0.12 at 25° C. In particular, the refractive index anisotropy is preferably from 0.10 to 0.12 for a thin cell gap or is preferably from 0.08 to 0.10 for a thick cell gap.

The rotational viscosity (γ1) is preferably not more than 150, more preferably not more than 130, and especially preferably not more than 120.

In the liquid crystal layer of the liquid crystal display device of the present invention, it is preferred that the function Z of the rotational viscosity and the refractive index anisotropy have a specific value.

[Math. 1]

$$Z = \gamma^1 / \Delta n^2$$

(where γ1 represents rotational viscosity, and Δn represents refractive index anisotropy)

Z is preferably not more than 13000, more preferably not more than 12000, and especially preferably not more than 11000.

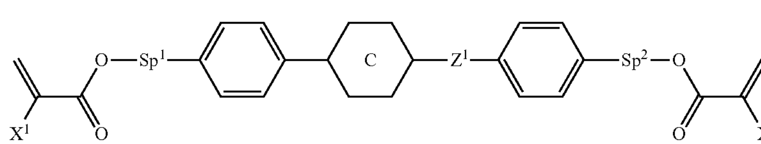
In the case where the liquid crystal layer of the liquid crystal display device of the present invention is used in an active-matrix display device, the liquid crystal layer needs to have a specific resistance of not less than 10^{12} (Ω·m), preferably 10^{13} (Ω·m), and more preferably not less than 10^{14} (Ω·m).

In addition to the above-mentioned compounds, the liquid crystal layer of the liquid crystal display device of the present invention may contain, for example, general nematic liquid crystal, smectic liquid crystal, cholesteric liquid crystal, antioxidants, ultraviolet absorbers, and polymerizable monomers, depending on the application thereof.

The polymerizable monomer is preferably a difunctional monomer represented by General Formula (V).

[Chem. 18]

(V)



(where X^1 and X^2 each independently represent a hydrogen atom or a methyl group;

Sp^1 and Sp^2 each independently represent a single bond, an alkylene group having 1 to 8 carbon atoms, or —O—$(CH_2)_s$— (where s represents an integer from 2 to 7, and the oxygen atom is bonded to an aromatic ring);

Z^1 represents —OCH_2—, —CH_2O—, —COO—, —OCO—, —CF_2O—, —OCF_2—, —CH_2CH_2—, —CF_2CF_2—, —CH═CH—OCO—, —CH═CH—OCO—, —COO—CH═CH—, —OCO—CH═CH—, —COO—CH_2CH_2—, —OCO—CH_2CH_2—, —CH_2CH_2—COO—, —CH_2CH_2—OCO—, —COO—CH_2—, —OCO—CH_2—, —CH_2—COO—, —CH_2—OCO—, —CY^1═CY^2— (where Y^1 and Y^2 each independently represent a fluorine atom or a hydrogen atom), —C≡C—, or a single bond; and

C represents a 1,4-phenylene group, a trans-1,4-cyclohexylene group, or a single bond, and in each 1,4-phenylene group in the formula, any hydrogen atom is optionally substituted with a fluorine atom)

Diacrylate derivatives in which X^1 and X^2 each represent a hydrogen atom and dimethacrylate derivatives in which X^1 and X^2 are each a methyl group are preferred, and compounds in which one of X^1 and X^2 represents a hydrogen atom and in which the other one thereof represents a methyl group are also preferred. Among these compounds, the rate of polymerization is the highest in diacrylate derivatives and the lowest in dimethacrylate derivatives, and the rate of polymerization of unsymmetrical compounds is intermediate therebetween. Hence, an appropriate compound can be employed on the basis of the intended application. In PSA display devices, dimethacrylate derivatives are especially preferred.

Sp^1 and Sp^2 each independently represent a single bond, an alkylene group having 1 to 8 carbon atoms, or —O—$(CH_2)_n$—; in an application to PSA display devices, at least one of Sp^1 and Sp^2 is preferably a single bond, and compounds in which Sp^1 and Sp^2 each represent a single bond and compounds in which one of Sp^1 and Sp^2 is a single bond and in which the other one thereof represents an alkylene group having 1 to 8 carbon atoms or —O—$(CH_2)_n$— are preferred. In this case, an alkyl group having a carbon number of 1 to 4 is preferably employed, and s preferably ranges from 1 to 4.

Z^1 is preferably —OCH_2—, —CH_2O—, —COO—, —OCO—, —CF_2O—, —OCF_2—, —CH_2CH_2—, —CF_2CF_2—, or a single bond; more preferably —COO—, —OCO—, or a single bond; and especially preferably a single bond.

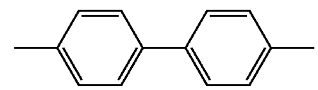
C represents a 1,4-phenylene group of which any hydrogen atom is optionally substituted with a fluorine atom, a trans-1,4-cyclohexylene group, or a single bond; and a 1,4-phenylene group and a single bond are preferred. In the case where C does not represent a single bond but represents a ring structure, Z^1 preferably represents a linking group as well as a single bond; in the case where C represents a single bond, Z^1 is preferably a single bond.

From these viewpoints, a preferred ring structure between Sp^1 and Sp^2 in General Formula (V) is particularly as follows.

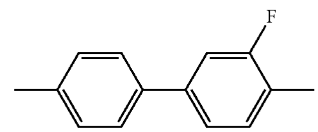
In General Formula (V), in the case where C represents a single bond and where the ring structure consists of two rings, the ring structure is preferably represented by any of Formulae (Va-1) to (Va-5), more preferably Formulae (Va-1) to (Va-3), and especially preferably Formula (Va-1).

[Chem. 19]

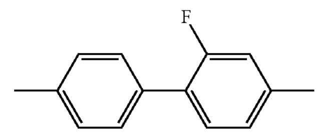
(Va-1)



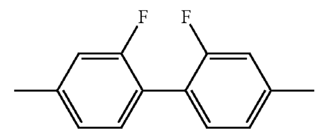
(Va-2)



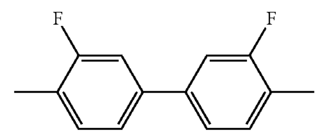
(Va-3)



(Va-4)



(Va-5)



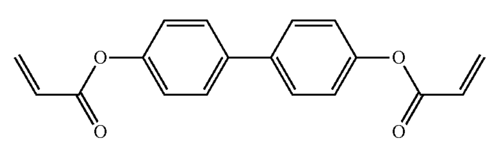
(in the formulae, the two ends of each structure are bonded to Sp^1 and Sp^2, respectively)

Polymerizable compounds having such skeletons enable uneven display to be reduced or eliminated in PSA liquid crystal display devices because such polymerizable compounds have optimum alignment regulating force after being polymerized and thus produce a good alignment state.

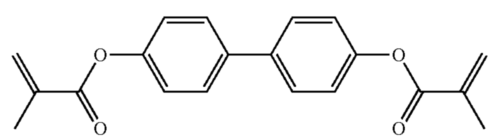
Accordingly, the polymerizable monomer is especially preferably any of compounds represented by General Formulae (V-1) to (V-4), and most preferably the compound represented by General Formula (V-2).

[Chem. 20]

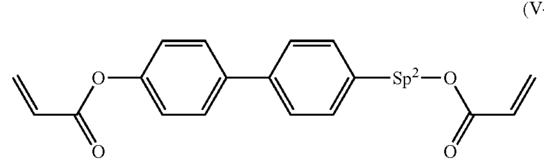
(V-1)



(V-2)

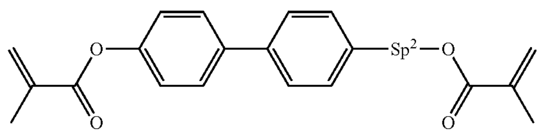


(V-3)



-continued

(V-4)



(in the formulae, Sp^2 represents an alkylene group having 2 to 5 carbon atoms)

In the case where the polymerizable monomer is added, polymerization is carried out even without a polymerization initiator; however, a polymerization initiator may be used to promote the polymerization. Examples of the polymerization initiator include benzoin ethers, benzophenones, acetophenones, benzyl ketals, and acyl phosphine oxides. In order to enhance storage stability, a stabilizer may be added. Examples of usable stabilizers include hydroquinones, hydroquinone monoalkylethers, tertiary butylcatechol, pyrogallols, thiophenols, nitro compounds, β-naphthylamines, β-naphthols, and nitroso compounds.

The polymerizable-monomer-containing liquid crystal layer is useful in liquid crystal display devices, and especially useful in liquid crystal display devices driven by an active matrix; hence, such a liquid crystal layer can be used in liquid crystal display devices of a PSA mode, PSVA mode, VA mode, IPS mode, and ECB mode.

The polymerizable monomer contained in the polymerizable-monomer-containing liquid crystal layer is polymerized by being irradiated with ultraviolet with the result that liquid crystal molecules can be aligned, and such a liquid crystal layer is used in liquid crystal display devices in which the birefringence of the liquid crystal composition is utilized to control the amount of light that is to be transmitted. Such a liquid crystal layer is useful in liquid crystal display devices, such as an AM-LCD (active matrix liquid crystal display device), a TN (twisted nematic liquid crystal display device), an STN-LCD (super twisted nematic liquid crystal display device), an OCB-LCD, and an IPS-LCD (in-plane switching liquid crystal display device), particularly useful in an AM-LCD, and can be used in transmissive or reflective liquid crystal display devices.

(Color Filter)

The color filter used in the present invention contains an organic pigment, so that light having a specific wavelength can be absorbed and that light having another specific wavelength can be transmitted.

Any substrate can be used provided that light can pass through it, and a proper substrate may be selected on the basis of application. Examples thereof include substrates made of resins or inorganic materials, and a glass substrate is particularly preferred.

The color filter includes the substrate and the organic pigment, and the organic pigment may be dispersed in the substrate or present only on the surface of the substrate. The organic pigment may be dispersed in resin, and the resin may be formed into a shape; alternatively, the organic pigment may be dispersed in the form of a coating on the surface of the substrate. A color filter in which a dispersion liquid of the pigment has been applied to the surface of a glass substrate, for example, can be suitably used in luminous display devices such as liquid crystal display devices and organic EL display devices.

The color filter can have any shape; arbitrary shapes including a plate, a film, a lens, a sphere, a shape partially having a three-dimensional roughness, and a shape having a fine uneven surface profile can be employed.

[Organic Pigment]

Examples of the organic pigment used in the present invention include phthalocyanine pigments, insoluble azo pigments, azo lake pigments, anthraquinone pigments, quinacridone pigments, dioxazine pigments, diketopyrrolopyrrole pigments, anthrapyrimidine pigments, anthanthrone pigments, indanthrone pigments, flavanthrone pigments, perinone pigments, perylene pigments, thioindigo pigments, triarylmethane pigments, isoindolinone pigments, isoindolin pigments, metal complex pigments, quinophthalone pigments, and dye lake pigments. A proper pigment can be determined on the basis of the wavelength of light to be transmitted.

In the case of a red color filter, a red pigment can be used; specifically, pigments having a high light transmittance for light with a wavelength ranging from 600 nm to 700 nm can be employed. Such pigments can be used alone or in combination. Specific examples of a preferred pigment include C.I. Pigment Red 81, 122, 177, 209, 242, and 254 and Pigment Violet 19. Among these, C.I. Pigment Red 254 is particularly preferred and has a maximum light transmittance for light having a wavelength from 660 nm to 700 nm.

The red color filter can further contain at least one organic pigment selected from the group consisting of C.I. Pigment Orange 38 and 71 and C.I. Pigment Yellow 150, 215, 185, 138, and 139 for toning.

In the case of a green color filter, a green pigment can be used; in particular, pigments having a maximum light transmittance for light having a wavelength from 500 nm to 600 nm can be employed. Such pigments can be used alone or in combination. Specific examples of a preferred pigment include C.I. Pigment Green 7, 36, and 58. Among these, C.I. Pigment Green 58 is particularly preferred and has a maximum light transmittance for light having a wavelength from 510 nm to 550 nm.

The green color filter can further contain at least one organic pigment selected from the group consisting of C.I. Pigment Yellow 150, 215, 185, and 138 for toning.

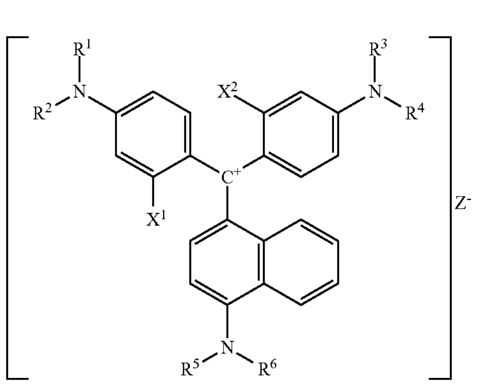
In the case of a blue color filter, a blue pigment can be used; in particular, pigments having a maximum light transmittance for light having a wavelength from 400 nm to 500 nm can be employed. Such pigments can be used alone or in combination. Specific examples of a preferred pigment include C.I. Pigment Blue 15:3 and 15:6 and triarylmethane pigments such as C.I. Pigment Blue 1 and/or a triarylmethane pigment represented by General Formula (1) (in the formula, R^1 to R^6 each independently represent a hydrogen atom, an optionally substituted alkyl group having 1 to 8 carbon atoms, or an optionally substituted aryl group; in the case where R^1 to R^6 are each an optionally substituted alkyl group, R^1, R^3, and R^5 may be combined to adjoining R^2, R^4, and R^6 to form ring structures, respectively; X^1 and X^2 each independently represent a hydrogen atom, a halogen atom, or an optionally substituted alkyl group having 1 to 8 carbon atoms; Z— is at least one anion selected from heteropolyoxometalate anion represented by (P2MoyW18-yO62)6-/6 in which y is an integer of 0, 1, 2, or 3, heteropolyoxometalate anion represented by (SiMoW11O40)4-/4, and lacunary Dawson-type phosphotungstic acid heteropolyoxometalate anion; and in the case where one molecule has multiple structures represented by General Formula (1), these structures may be the same as or different from each other).

In General Formula (1), R^1 to R^6 may be the same as or different from each other. Hence, —NRR moieties (RR represents any of combinations of R^1 and R^2, R^3 and R^4, and R^5 and R^6) may be symmetric or asymmetric.

C.I. Pigment Blue 15:3 has a maximum light transmittance for light having a wavelength from 440 nm to 480 nm, C.I. Pigment Blue 15:6 has a maximum light transmittance for light having a wavelength from 430 nm to 470 nm, and the triarylmethane pigment has a maximum light transmittance for light having a wavelength from 410 nm to 450 nm.

The blue color filter can further contain at least one organic pigment selected from the group consisting of C.I. Pigment Violet 23 and 37 and C.I. Pigment Blue 15, 15:1, 15:2, and 15:4 for toning.

[Chem. 21]



(1)

In the case where the color filter can be produced by a technique in which pigment dispersions prepared from the above-mentioned organic pigments are applied onto substrates, such pigment dispersions may contain known pigment dispersants and solvents in addition to the organic pigments. Dispersion liquids in which the organic pigments have been preliminarily dispersed in solvents or pigment dispersants are prepared, and the prepared dispersion liquids can be applied to a substrate; examples of a technique for the application include spin coating, roller coating, an ink jet technique, spray coating, and printing.

The organic pigments applied to the substrate are dried, and production of the color filter may be completed in this state. In the case where the pigment dispersions contain curable resins, curing by exposure to heat or an active energy ray may be carried out to complete the production of the color filter. Furthermore, an additional step may be carried out, in which a volatile component in the coating is removed by heating with a heater, such as a hot plate or an oven, at 100 to 280° C. for a predetermined time (post-baking).

[State of Pigment Particles in Color Filter]

In the color filter used in the present invention, an organic pigment of which the particles have a particle size greater than 1000 nm has a volume fraction of not more than 1%, and an organic pigment of which the particles have a particle size ranging from 40 nm to 1000 nm has a volume fraction of not more than 25%. In the color filter, the state of the organic pigments which are present in the completed color filter has the largest effect on a reduction in defective display such as voids, uneven alignment, and screen burn-in. Defining the particles of the organic pigments which are present in the completed color filter enables the color filter to eliminate the above-mentioned defective display.

The particles having a particle size ranging from 40 nm to 1000 nm are higher-order particles made by the agglomeration of primary particles, such as secondary particles, tertiary particles, or quaternary particles; and the volume fraction thereof is preferably not more than 15%.

If particles having a particle size ranging from 100 nm to 1000 nm are excess, the particles affect a display state. The volume fraction of the particles having a particle size ranging from 100 nm to 1000 nm is preferably not more than 7%, and more preferably not more than 3%.

In the organic pigments, coarse particles having a particle size greater than 1000 nm have an adverse effect on a display state and are therefore not preferred; hence, its content needs to be not more than 1%. The content may be measured by observing the surface of the color filter with, for instance, an appropriate optical microscope.

[Ultra-Small Angle X-Ray Scattering Profile]

The volume fraction of particles having a particle size of not more than 1000 nm can be determined by analysis of an ultra-small angle X-ray scattering profile obtained by ultra-small angle X-ray scattering.

In particular, the determination of the volume fraction includes the following steps: the ultra-small angle X-ray scattering profile of an organic pigment (measured scattering profile) is obtained by ultra-small angle X-ray scattering (step (A)); assuming that the organic pigment consists of spherical particles each having a radius R and has dispersion in particle size distribution, its theoretical scattering profile is obtained from a hypothetical radius R_1 and hypothetical normalized variance by simulation (step (B)); curve fitting of the theoretical scattering profile with the measured scattering profile is performed to obtain the residual sum of squares Z of the theoretical scattering profile and the measured scattering profile (step (C)); and other radii R_{n+1} (n is an integer, $R_n<R_{n+1}$) and corresponding hypothetical normalized variance are added to form multiple particle size distribution models, the steps (B) and (C) are repeated n times until the residual sum of squares Z, which is obtained in the step (C), reaches 2% or lower, and at least one of the primary particle size of the organic pigment, the average particle size of higher-order particles thereof, the normalized variance, and the volume fraction is determined from the result of the curve fitting of the theoretical scattering profile with the measured scattering profile (step (D)).

In the ultra-small angle X-ray scattering (USAXS), diffuse scattering and diffraction caused not only in a small angle region at a scattering angle of $0.1<(2\theta)<10°$ but also in an ultra-small angle region at a scattering angle of $0°<(2\theta)\leq 0.1°$ are simultaneously observed. In small angle X-ray scattering, in the case where a substance has regions each having a size approximately from 1 to 100 nm and a different electron density, the diffuse scattering of an X-ray can be observed from such a difference in the electron density; in the ultra-small angle X-ray scattering, in the case where a substance has regions each having a size approximately from 1 to 1000 nm and a different electron density, the diffuse scattering of an X-ray can be observed from such a difference in the electron density. The particle size of a measuring object is determined on the basis of the scattering angle and scattering intensity thereof.

The main techniques which enable the ultra-small angle X-ray scattering are two techniques: use of an advanced technology for controlling an optical system, in which the width of the wavelength of an incident X-ray and a beam diameter are narrowed to reduce the background scattering intensity in an ultra-small angle region; and accurate measurement of part having a small scattering angle with a distance between the sample and a detector, so-called camera length, being elongated as much as possible. The former is mainly employed for ultra-small angle X-ray scattering with small equipment used in a laboratory.

A program used to obtain particle size distribution from a small-angle X-ray scattering curve can be preferably a program such as NANO-solver (manufactured by Rigaku Corporation) or GIFT (manufactured by PANalytical B.V.).

In measurement of the particle size properties of the organic pigment, sufficient scattering intensity can be measured when the brightness of an incident X-ray in an X-ray scattering apparatus is not less than 10^6 Brilliance (photons/sec/mm^2/mrad^2/0.1% bandwidth), and preferably not less than 10^7 Brilliance. In the case where the substrate of a coating is, for example, glass, an X-ray is easily absorbed, and thus the brightness of the incident X-ray is significantly insufficient; hence, in order to accurately measure the primary particle size of the organic pigment, the average particle size of higher-order particles thereof, the normalized variance, and the volume fraction, the brightness of the incident X-ray is preferably not less than 10^{16} Brilliance, and more preferably not less than 10^{18} Brilliance.

In order to use a high-brightness X-ray source with not less than 10^{16} Brilliance, for instance, the light sources of the large-scale synchrotron radiation facilities, such as SPring-8 in Hyogo Prefecture and Photon Factory in Ibaraki Prefecture, can be used. In such facilities, an appropriate camera length can be determined to select the intended scattering region. Moreover, several types of metal absorber plates called attenuator can be used on the incident light side in order to produce sufficient scattering intensity, to prevent a sample from being damaged, and to protect a detector; and the exposure time can be properly adjusted to be approximately between 0.5 and 60 seconds to select measurement conditions suitable for a wide range of purposes. Examples of the attenuator include thin films made of Au, Ag, or molybdenum.

In a specific process of the measurement, in the step (A), a color filter is attached to, for example, the sample holder or sample stage of a commercially available X-ray diffractometer, and then scattering intensity I is measured at each of scattering angles (2θ) less than 10° to obtain a small angle X-ray scattering profile (measured scattering profile).

In an ultra-small angle scattering apparatus which is used for analyzing a coating on a glass substrate by synchrotron radiation, white light taken from a circular accelerator called a storage ring is monochromatized with a double crystal monochromator in order to employ a beam having a wavelength in an X-ray region (e.g., 1 Å) as a source, the beam is radiated to the coating attached to a sample stage, a two-dimensional detector is exposed to a scattered light for a predetermined time, the obtained scattering profile that is concentric circular is averaged to be one dimensional, the resulting profile is converted to scattering intensities I corresponding to scattering angles (2θ) less than 10°, thereby obtaining a small angle X-ray scattering profile (measured scattering profile). This procedure is defined as the step (A).

Then, in the step (B), assuming that the organic pigment consists of spherical particles each having a radius R and has dispersion in particle size distribution, a theoretical scattering profile is obtained from a hypothetical radius R_1 and hypothetical normalized variance by simulation with commercially available analytical software on the basis of the measured scattering profile.

In general, in the case where a substance has regions with a difference in electron density $\Delta\rho(r)$, the scattering intensity I can be approximated as represented by Equation (1).

[Math. 2]

$$I(q) = \left(\int_V \Delta\rho(r)e^{iq\cdot r}dr\right)^* \int_V \Delta\rho(r)e^{iq\cdot r}dr = |F(q)|^2 S(q) \tag{1}$$

In Equation (1), q represents a scattering vector, and V represents the domain of a volume integral and means that the whole substance is subjected to the integral. F(q) is a form factor, and S(q) is a structure factor; in the case where particles exist in a substance at random, S(q) is equal to 1. The scattering vector q is represented by Equation (2).

[Math. 3]

$$q = \frac{4\pi}{\lambda}\sin\frac{2\theta}{2} \tag{2}$$

In Equation (2), λ is the wavelength of an X-ray, and 2θ is a scattering angle. If the particles are spheres each having a radius R, the form factor F(q) in Equation (1) is represented by Equation (3).

[Math. 4]

$$F(q) = \Delta\rho\int_0^{2\pi}d\varphi\int_0^{\pi}d\theta\int_0^{R}e^{iqr\cos\theta}r^2\sin\theta dr = \Delta\rho\frac{4\pi}{q^3}(\sin(qR) - qR\cos(qR)) \tag{3}$$

Accordingly, when the form factor F(q) is calculated on the basis of the assumption of the value of the hypothetical radius R, the scattering intensity I can be described from Equations (1), (2), and (3). Such scattering intensity I is, however, based merely on the assumption that particles in a substance each have a constant size (the radius R is constant). In an actual substance, to the contrary, particles rarely have a constant size but generally have a variation in size to some extent (dispersion in particle size distribution). In the present invention, since such an organic pigment having dispersion in particle size distribution needs to be subjected to correct and accurate measurement of particle size distribution, it is unavoidably necessary to assume dispersion in particle size distribution.

In view of such dispersion in particle size distribution, the scattering intensity I can be obtained by gathering scattering derived from each of particles having various sizes. A distribution function used for assuming dispersion in particle size distribution can be a known distribution function employed in statistics; taking dispersion in particle size distribution in an actual substance into consideration, a gamma distribution function is preferred. The gamma distribution function is represented by Equation (4).

[Math. 5]

$$P_{R_0}^{M}(R) = \frac{1}{\Gamma(M)}\left(\frac{M}{R_0}\right)^M e^{-\frac{M\cdot R}{R_0}} R^{-1+M} \tag{4}$$

In the equation, R_0 is the average radius of spherical particles, and M is a parameter of the spread of particle size distribution. When it can be assumed that the particle size distribution in a substance can be obtained from such a gamma distribution function and that the scattering intensity I can be obtained by gathering scattering derived from each of particles having various radii R_1 (the average radius is R_0), the scattering intensity I in the case where dispersion in particle size distribution exists is represented by Equation (5) from Equations (3) and (4).

[Math. 6]

$$I(q, R_0, M) = \int_0^\infty |F(q, R)|^2 P_{R_0}^M(R) \frac{1}{R^3} dR \tag{5}$$

M in Equation (5), which is a parameter of the spread of particle size distribution, is output as normalized variance σ(%) for an analytical result by conversion with Equation (6).

[Math. 7]

$$\sigma(\%) = \frac{1}{\sqrt{M}} \times 100 \tag{6}$$

From Equation (5), the scattering intensity I at a scattering angle (2θ) is calculated from a hypothetical radius R_1 and hypothetical normalized variance by simulation to obtain a theoretical scattering profile in the step (B).

Then, in the step (C), the curve fitting of the theoretical scattering profile calculated from the scattering intensity I with the measured scattering profile is carried out by a least squares method.

In the profile fitting, variables to be refined are an average particle size (nm) and normalized variance (%). The profile fitting is carried out such that the residual sum of squares Z of the measured profile and the theoretical scattering profile becomes minimum by a least squares method; and the smaller the residual sum of squares Z is, the higher the accuracy of the particle size analysis is. In general, at the residual sum of squares Z of lower than 2%, both of the profiles are visually substantially fitted to each other, which may be regarded as the convergence. The residual sum of squares Z is preferably lower than 1%, and more preferably lower than 0.5%. The average primary particle size and normalized variance which are variables at the convergence can be obtained as analytical results.

In the case where X-ray scattering is observed also in an ultra-small angle scattering region in the step (A), the analytical range covers even a relatively large particle size. Hence, if one particle size distribution, namely one average primary particle size, and normalized variance are assumed in the step (B), the fitting analysis in the step C may result in insufficient lowering of the residual sum of squares Z and thus show unsatisfactory fitting of the measured profile to the theoretical scattering profile.

The reason for it is presumed as follows: it is not that the only one particle size distribution exists but that several particle size distributions exist because of the presence of pigment particles having a larger particle size and higher-order agglomerates. A new particle size distribution model is therefore introduced on the basis of this presumption.

In the step (D), other radii R_{n+1} (n is an integer, $R_n<R_{n+1}$) and corresponding hypothetical normalized variance are added to form multiple particle size distribution models, and the steps (B) and (C) are repeated n times until the residual sum of squares Z, which is obtained in the step (C), reaches 2% or lower.

Specifically, a new particle size distribution model for a larger average particle size is assumed, and the radius is determined as R_2 ($R_2>R_1$). When the corresponding scattering intensities I are defined as I(1) and I(2), the left side of Equation (5) for scattering intensity is modified into Equations (7) and (8), respectively.

[Math. 8]

$$I(1) = I(q, R_1, M_1) = \int_0^\infty |F(q, R)|^2 P_{R_1}^{M_1}(R) \frac{1}{R^3} dR \tag{7}$$

M_1 is a parameter of the spread of the first particle size distribution.

[Math. 9]

$$I(2) = I(q, R_2, M_2) = \int_0^\infty |F(q, R)|^2 P_{R_2}^{M_2}(R) \frac{1}{R^3} dR \tag{8}$$

M_2 is a parameter of the spread of the second particle size distribution.

Likewise, in the case where distributions at a third radius R3 or more are assumed, the scattering intensities can be I(3), I(4) . . . , and I(n).

Total scattering intensity I_{Total} in a particle size distribution model having two average particle sizes is represented by Equation (9).

$$I_{Total}=k(1)I(1)+k(2)I(2) \tag{9}$$

k(1) and k(2) are scale factors which represent the composition ratios of corresponding distributions.

Similarly, a particle size distribution model having three or more average particle sizes is assumed, and the total scattering intensity of n particle size distribution models in total can be represented by Equation (10).

$$I_{Total}=k(1)I(1)+k(2)I(2)+ \ldots +k(n)I(n) \tag{10}$$

In the above-mentioned multiple particle size distributions, for example, the volume fractions w(1), w(2), . . . , and w(n) in n particle size distributions are in a ratio represented by Equation (11).

$$w(1):w(2): \ldots :w(n)=k(1):k(2): \ldots :k(n) \tag{11}$$

Variables refined in the profile fitting are the average particle size (nm) in each particle size distribution, normalized variance which shows the width of a corresponding particle size distribution (%), and the volume fraction in each particle size distribution (%). The profile fitting is carried out such that the value of Z which is the residual sum of squares of the measured profile and the total theoretical scattering profile becomes minimum, and then each variable is determined.

If the profile fitting in the step (D) does not well converge, in other words, if the minimum value of the residual sum of squares Z cannot be determined, the cause of this circumstance may be that the types of variables to be determined are in excess. In this case, the normalized valiance of each particle size distribution may be fixed with reference to normalized valiance obtained in the step (C). Owing to this procedure, the profile fitting by a least squares method with fewer variables can easily converge. Thus, the average particle size (nm) in each particle size distribution, the normalized variance (%) thereof, and the volume fraction in each particle size distribution (%) can be obtained as analytical results.

(Alignment Film)

In the liquid crystal display device of the present invention, in the case where alignment films need to be provided on the liquid crystal composition sides of the first and second substrates to align the molecules of the liquid crystal composition, the alignment films are disposed between a color filter and the liquid crystal layer in the liquid crystal display device. Each alignment film, however, has a thickness of not more than 100 nm even when the thickness is large; hence, the alignment films do not completely block the interaction between a colorant used in the color filter, such as a pigment, and a liquid crystal compound used in the liquid crystal layer.

In a liquid crystal display device in which an alignment film is not used, the interaction between a colorant used in the color filter, such as a pigment, and a liquid crystal compound used in the liquid crystal layer is larger.

The material of the alignment films can be a transparent organic material such as polyimide, polyamide, BCB (benzocyclobutene polymer), or polyvinyl alcohol; in particular, polyimide alignment films formed though imidizing of a polyamic acid synthesized from diamine such as an aliphatic or alicyclic diamine (e.g., p-phenylenediamine and 4,4'-diaminodiphenyl methane), an aliphatic or alicyclic tetracarboxylic acid anhydride such as butanetetracarboxylic acid anhydride or 2,3,5-tricarboxycyclopentyl acetic acid anhydride, and an aromatic tetracarboxylic acid anhydride such as pyromellitic acid dianhydride are preferred. In this case, rubbing is generally carried out to give an alignment function; however, in the case where each alignment film is used as, for instance, a vertical alignment film, the alignment film can be used without the alignment function being developed.

Materials usable for the alignment films may be materials in which compounds contain, for instance, chalcone, cinnamate, cinnamoyl, or an azo group. Such materials may be used in combination with another material such as polyimide or polyamide; in this case, the alignment films may be rubbed or treated by a photo-alignment technique.

In general formation of alignment films, the above-mentioned material of the alignment films is applied onto substrates by, for example, spin coating to form resin films; besides, uniaxial stretching or a Langmuir-Blodgett technique can be employed.

(Transparent Electrode)

In the liquid crystal display device of the present invention, the material of a transparent electrode can be a conductive metal oxide. Usable metal oxides are indium oxide (In_2O_3), tin oxide (SnO_2), zinc oxide (ZnO), indium tin oxide (In_2O_3—SnO_2), indium zinc oxide (In_2O_3—ZnO), niobium-doped titanium dioxide ($Ti_{1-x}b_xO_2$), fluorine-doped tin oxide, graphene nanoribbon, and metal nanowires; among these, zinc oxide (ZnO), indium tin oxide (In_2O_3—SnO_2), and indium zinc oxide (In_2O_3—ZnO) are preferred. A transparent conductive film formed of any of such materials can be patterned by photo-etching or a technique involving use of a mask.

The liquid crystal display device is combined with a backlight for various applications such as liquid crystal television sets, computer monitors, mobile phones, smartphone displays, laptops, portable information terminals, and digital signage. Examples of the back light include cold-cathode tube backlights and virtually white backlights with two peak wavelengths or backlights with three peak wavelengths; in the backlight with two or three peak wavelengths, light-emitting diodes using inorganic materials or organic EL devices are used.

Examples

Although some preferred embodiments of the present invention will now be described in detail with reference to Examples, the present invention is not limited to Examples. In compositions which will be described in Examples and Comparative Examples, the term "%" refers to "mass %".

In Examples, the following properties were measured.

T_{ni}: Nematic phase-isotropic liquid phase transition temperature (° C.)

Δn: Refractive index anisotropy at 25° C.

Δ∈: Dielectric anisotropy at 25° C.

η: Viscosity at 20° C. (mPa·s)

γ_1: Rotational viscosity at 25° C. (mPa·s)

d_{gap}: Gap between first and second substrates in cell (μm)

VHR: Voltage holding ratio (%) at 70° C.

(ratio, represented by %, of a measured voltage to the initially applied voltage, which was obtained as follows: a liquid crystal composition was put into a cell having a thickness of 3.5 μm, and the measurement was carried out under the conditions of an applied voltage of 5 V, a frame time of 200 ms, and a pulse width of 64 μs)

ID: Ion density at 70° C. (pC/cm^2)

(ion density obtained as follows: a liquid crystal composition was put into a cell having a thickness of 3.5 μm, and measurement was carried out with an MTR-1 (manufactured by TOYO Corporation) under the conditions of an applied voltage of 20 V and a frequency of 0.05 Hz)

Screen Burn-in:

In evaluation of screen burn-in in a liquid crystal display device, a certain fixed pattern was displayed in a display area for 1000 hours, and then an image was shown evenly on the whole of the screen. Then, the degree of an afterimage of the fixed pattern was visually observed, and result of the observation was evaluated on the basis of the following four criteria:

Excellent: No afterimage observed

Good: Slight afterimage observed, but acceptable

Bad: Afterimage observed, unacceptable

Poor: Afterimage observed, quite inadequate

In Examples, compounds are abbreviated as follows.

(Side Chain)

-n —C_nH_{2n+1} linear alkyl group having n carbon atoms

n- C_nH_{2n+1} linear alkyl group having n carbon atoms

-On —OC_nH_{2n+1} linear alkoxyl group having n carbon atoms

nO- $C_nH_{2n+1}O$— linear alkoxyl group having n carbon atoms

-V —CH═CH_2

V- CH_2═CH—

-VI —CH═CH—CH_3

IV- CH_3—CH═CH—

-2V —CH_2—CH_2—CH═CH_3

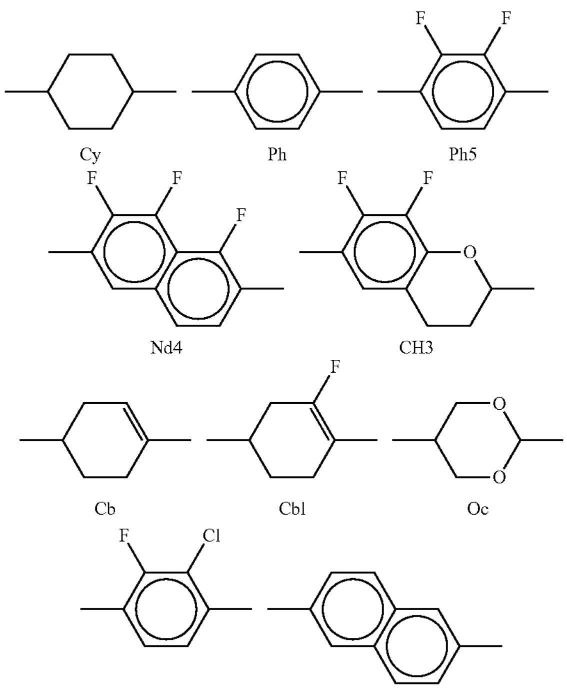
V2- CH_3═CH—CH_2—CH_2—

-2V1-CH_2—CH_2—CH═CH—CH_3

1V2- CH_3—CH═CH—CH_2—CH_2

(Ring Structure)

[Chem. 22]



Cy Ph Ph5 Nd4 CH3 Cb Cbl Oc Phl5 Nd

Production of Color Filter

Preparation of Pigment Dispersion Liquid

Synthesis Example 1

Synthesis of Copolymer a

In a nitrogen flow, 100 parts of xylene was held at 80° C.; and then a mixture of 68 parts of ethyl methacrylate, 29 parts of 2-ethylhexyl methacrylate, 3 parts of thioglycolic acid, and 0.2 parts of a polymerization initiator ("PERBUTYL® O" [active ingredient: t-butyl peroxy-2-ethylhexanoate, manufactured by NOF CORPORATION]) was added dropwise thereto under stirring over 4 hours. After the dropping was completed, 0.5 pats of "PERBUTYL® O" was added thereto every 4 hours, and the resulting product was stirred at 80° C. for 12 hours. After termination of the reaction, xylene was added thereto to adjust the nonvolatile content, thereby producing a xylene solution of a copolymer a with a 50% nonvolatile content.

Synthesis Example 2

Synthesis of Copolymer b

In a nitrogen flow, 100 parts of xylene was held at 80° C.; and then a mixture of 66 parts of ethyl methacrylate, 28 parts of 2-ethylhexyl methacrylate, 6 parts of thioglycolic acid, and 0.3 parts of a polymerization initiator ("PERBUTYL® O" [active ingredient: t-butyl peroxy-2-ethylhexanoate, manufactured by NOF CORPORATION]) was added dropwise thereto under stirring over 4 hours. After the dropping was completed, 0.5 pats of "PERBUTYL® O" was added thereto every 4 hours, and the resulting product was stirred at 80° C. for 12 hours. After termination of the reaction, a proper amount of xylene was added thereto to adjust the nonvolatile content, thereby producing a xylene solution of a copolymer b with a 50% nonvolatile content.

Synthesis Example 3

Synthesis of Polymer A

Into a flask equipped with a stirrer, a reflux condenser, a nitrogen inlet, and a thermometer, a mixture of 54.5 parts of xylene, 19.0 parts of the copolymer a obtained in Synthesis Example 1, 38.0 parts of the copolymer b, and 7.5 parts of a 20% aqueous solution of polyallylamine ("PAA-05" manufactured by NITTO BOSEKI CO., LTD., number average molecular weight of approximately 5,000) was put and then stirred at 140° C. under a nitrogen flow in order to perform a reaction at 140° C. for 8 hours while water was distilled off with a separator and the xylene was returned to the reaction solution.

After termination of the reaction, a proper amount of xylene was added thereto to adjust the nonvolatile content, thereby producing a polymer A as a modified polyamine having a 40% nonvolatile content. The resin has a weight average molecular weight of 10,000 and an amine value of 22.0 mg KOH/g.

Production Example 1

Production of Powder Pigment 1

FASTOGEN Green A110 manufactured by DIC Corporation (C.I. Pigment Green 58, brominated chlorinated zinc phthalocyanine) was used as a powder pigment 1.

Production Example 2

Production of Powder Pigment 2

To a mixture composed of 100 parts of the powder pigment 1 obtained in Production Example 1, 300 parts of heptane, and 10 parts of the polymer A, 300 parts of 1.25-mm zirconia beads were added. The resulting mixture was stirred for an hour at normal temperature with Paint Shaker (manufactured by Toyo Seiki Seisaku-sho, Ltd.) and then diluted with 200 parts of heptane. The zirconia beads were separated by filtration to obtain a pigment mixture liquid.

Into a separable flask equipped with a thermometer, a stirrer, a reflux condenser, and a nitrogen gas inlet, 400 parts of the pigment mixture liquid was put. Then, a solution of two parts of 2,2'-azobis(2-methylbutyronitrile) in a polymerizable monomer composition composed of five parts of methyl methacrylate and five parts of ethylene glycol dimethacrylate was added thereto. Stirring was continued at room temperature for 30 minutes, the temperature was subsequently increased to 80° C., and the reaction was continued at this temperature for 15 hours. The temperature was decreased, and then the resulting product was filtered. The obtained wet cake was dried with a hot air dryer at 100° for 5 hours and then ground with a grinder to produce a powder pigment 2.

Production Example 3

Production of Powder Pigment 3

With a double-arm kneader, 10 parts of the powder pigment 1, 100 parts of ground sodium chloride, and 10 parts of diethylene glycol were kneaded at 100° C. for 8 hours. After the kneading, 1000 parts of water at 80° C. was added thereto; and the resulting product was stirred for an hour, filtered, washed with hot water, dried, and ground to obtain a powder pigment 3.

Production Example 4

Production of Dispersion Liquid 1

To a mixture of 5 parts of the powder pigment 1 obtained in Production Example 1, 33.3 parts of propylene glycol monomethyl ether (PGMA), and 3 parts of the polymer A, 65 parts of 0.5-mm Sepra Beads were added. The resulting mixture was stirred for four hours with Paint Shaker (manufactured by Toyo Seiki Seisaku-sho, Ltd.). The Sepra Beads were separated from the resulting liquid mixture by filtration to obtain a dispersion liquid 1.

Production Example 5

Production of Dispersion Liquid 2

A dispersion liquid 2 was produced as in Production Example 4 except that the powder pigment 2 and BYK6919 (manufactured by BYK Japan KK) were used in place of the powder pigment 1 and the polymer A, respectively.

Production Example 6

Production of Dispersion Liquid 3

A dispersion liquid 3 was produced as in Production Example 5 except that 0.1 part of pyridine was further added relative to 5 parts of the powder pigment 2, 33.3 parts of PGMA, and 3 parts of BYK6919.

Production Example 7

Production of Dispersion Liquid 4

A dispersion liquid 4 was produced as in Production Example 6 except that morpholine replaced pyridine.

Production Example 8

Production of Dispersion Liquid 5

A dispersion liquid 5 was produced as in Production Example 6 except that piperidine replaced pyridine.

Production Example 9

Production of Powder Pigment 4 and Dispersion Liquid 6

An ∈-copper phthalocyanine pigment (FASTOGEN Blue EP-193 manufactured by DIC Corporation) was employed as a powder pigment 4. To a mixture of 5 parts of the powder pigment 4, 33.3 parts of propylene glycol monomethyl ether (PGMA), and 3 parts of the polymer A, 65 parts of 0.5-mm Sepra Beads were added. The resulting mixture was stirred for four hours with Paint Shaker (manufactured by Toyo Seiki Seisaku-sho, Ltd.). The Sepra Beads were separated from the resulting liquid mixture by filtration to obtain a dispersion liquid 6.

Production Example 10

Production of Powder Pigment 5 and Dispersion Liquid 8

A diketopyrrolopyrrole red pigment PR254 ("IRGAPHOR Red B-CF" manufactured by Ciba Specialty Chemicals; R-1) was employed as a powder pigment 5. To a mixture of 5 parts of the powder pigment 5, 33.3 parts of propylene glycol monomethyl ether (PGMA), and 3 parts of the polymer A, 65 parts of 0.5-mm Sepra Beads were added. The resulting mixture was stirred for four hours with Paint Shaker (manufactured by Toyo Seiki Seisaku-sho, Ltd.). The Sepra Beads were separated from the resulting liquid mixture by filtration to obtain a dispersion liquid 8.

Production of Color Filter

Production Example 11

Production of Color Filter 1

A cover glass (borosilicate cover glass manufactured by TGK) was placed on a spin coater (Opticoat MS-A100 manufactured by MIKASA CO., LTD), and 1.5 ml of the dispersion liquid 1 obtained in Production Example 4 was applied thereto at 600 rpm. The obtained coating product was dried in a thermostatic oven at 90° C. for 3 minutes and then heated at 230° C. for 3 hours to produce a color filter 1. The color filter 1 had a maximum light transmittance for light having a wavelength of 523 nm. FIG. **3** illustrates the transmission spectrum therein.

Production Example 12

Production of Color Filter 2

A color filter 2 was produced as in Production Example 11 except that the dispersion liquid 2 was used instead of the dispersion liquid 1. The color filter 2 had a maximum light transmittance for light having a wavelength of 522 nm. FIG. **3** illustrates the transmission spectrum therein.

Production Example 13

Production of Color Filter 3

A color filter 3 was produced as in Production Example 11 except that the dispersion liquid 3 was used instead of the dispersion liquid 1. The color filter 3 had a maximum light transmittance for light having a wavelength of 521 nm. FIG. **3** illustrates the transmission spectrum therein.

Production Example 14

Production of Color Filter 4

A color filter 4 was produced as in Production Example 11 except that the dispersion liquid 4 was used instead of the dispersion liquid 1. The color filter 4 had a maximum light transmittance for light having a wavelength of 523 nm. FIG. **4** illustrates the transmission spectrum therein.

Production Example 15

Production of Color Filter 5

A cover glass (borosilicate cover glass manufactured by TGK) was placed on a spin coater (Opticoat MS-A100 manufactured by MIKASA CO., LTD), and 1.5 ml of the dispersion liquid 4 obtained in Production Example 7 was applied thereto at 600 rpm. The obtained coating product was dried in a thermostatic oven at 90° C. for 3 minutes to produce a color filter 5. The color filter 5 had a maximum light transmittance for light having a wavelength of 521 nm. FIG. **4** illustrates the transmission spectrum therein.

Production Example 16

Production of Color Filter 6

A color filter 6 was produced as in Production Example 11 except that the dispersion liquid 5 replaced the dispersion liquid 1.

Production Example 17

Production of Color Filter 7

A color filter 7 was produced as in Production Example 15 except that the dispersion liquid 3 replaced the dispersion liquid 4. The color filter 7 had a maximum light transmittance for light having a wavelength of 515 nm. FIG. **4** illustrates the transmission spectrum therein.

Production Example 18

Production of Color Filter 8

A color filter 8 was produced as in Production Example 11 except that the dispersion liquid 6 replaced the dispersion liquid 1. The color filter 8 had a maximum light transmittance for light having a wavelength of 435 nm.

Production Example 19

Production of Color Filter 9

In the procedure of Production Example 6, the powder pigment 2 was changed to the powder pigment 4 used in Production Example 9 in order to produce a dispersion liquid 7. A color filter 9 was produced as in Production Example 11 except that the dispersion liquid 7 replaced the dispersion liquid 1. The color filter 9 had a maximum light transmittance for light having a wavelength of 435 nm.

Production Example 20

Production of Color Filter 10

A color filter 10 was produced as in Production Example 11 except that the dispersion liquid 8 replaced the dispersion liquid 1.

Production Example 21

Production of Color Filter 11

In the procedure of Production Example 6, the powder pigment 2 was changed to the powder pigment 5 used in Production Example 10 in order to produce a dispersion liquid 9. A color filter 11 was produced as in Production Example 11 except that the dispersion liquid 9 replaced the dispersion liquid 1.

[Measurement of Volume Fraction of Organic Pigment in Color Filter]

(Observation of Coarse Particles with Microscope)

In each of the color filters 1 to 11, arbitrary five points were observed with an optical microscope Optiphot2, manufactured by NIKON CORPORATION, at a magnification of 2000, and no coarse particles with a size of not less than 1000 nm was found in any point.

(Analysis of Color Filters 1 to 11 by USAXS)

Each of the color filters 1 to 11 was attached to a sample holder made of Al with an adhesive tape and then fixed to a light-transmissive sample stage. The sample was subjected to analysis by ultra-small angle X-ray scattering under the following conditions, and the analysis showed three particle size distributions; of these, particles having a distribution with an average particle size ranging from 1 to 40 nm were defined as primary particles, particles having a distribution with an average particle size ranging from 40 to 100 nm were defined as secondary particles, and particles having a distribution with an average particle size ranging from 100 to 1000 nm were defined as tertiary particles. Table 1 shows the results of the analysis. The total of the secondary particles and the tertiary particles were defined as higher-order particles and shown in Table 1.

Analytical equipment and the analytical technique were as follows.

Analytical Equipment: Large-scale synchrotron radiation facility: a beam line owned by Frontier Soft Matter Beamline Consortium in SPring-8: BL03XU, second hatch

Analytical Mode: Ultra-small angle X-ray scattering (USAXS) Analytical conditions: wavelength of 0.1 nm, camera length of 6 m, beam spot size of 140 μm×80 μm, no attenuator, exposure time of 30 seconds, and 2θ=0.01 to 1.5°

Analytical Software: Fit2D for imaging of two-dimensional data and for conversion into one-dimensional data (software obtained from the website of European Synchrotron Radiation Facility [http://www.esrf.eu/computing/scientific/FIT2D/]) The particle size distribution was analyzed with software NANO-Solver (Ver 3.6) commercially available from Rigaku Corporation. The detail of an example of the analysis is as follows.

The following was predetermined: the scatterer model was spherical; the analytical method was a transmission method; and in the case of the green pigment A110, the particles were $C_{32}N_8ZnBr_{16}$ (density: 3.2), and a matrix was $C_6H_{12}O_3$ (density: 1).

Value of Z: The value had to be not more than 10% in a calculation only for the primary particles, not more than 5% in a calculation up to the secondary particles, and not more than 0.5% in a calculation up to the tertiary particles.

TABLE 1

	Primary particles			Secondary particles			Tertiary particles			
Color filter No.	Particle size (nm)	Normalized variance (%)	Volume fraction (%)	Particle size (nm)	Normalized variance (%)	Volume fraction (%)	Particle size (nm)	Normalized variance (%)	Volume fraction (%)	Total of higher-order particles (%)
Color filter 1	15	[40]	93.9	43	[40]	4.1	194	[40]	2.0	6.1
Color filter 2	21	[40]	95.5	54	[40]	3.4	195	[40]	1.1	4.5
Color filter 3	17	[40]	87.5	41	[40]	11.4	315	[40]	1.1	12.5
Color filter 4	16	[40]	91.8	52	[40]	6.4	184	[40]	1.8	8.2
Color filter 5	18	[40]	86.7	60	[40]	5.9	187	[40]	7.4	13.3
Color filter 6	17	[40]	81.0	50	[40]	15.8	210	[40]	3.2	19.0
Color filter 7	16	[40]	73.4	54	[40]	23.6	221	[40]	3.0	26.6
Color filter 8	15	[40]	92.2	40	[40]	4.5	201	[40]	1.3	7.8
Color filter 9	16	[40]	74.8	42	[40]	20.5	191	[40]	4.7	25.2
Color filter 10	16	[40]	91.5	45	[40]	5.6	185	[40]	2.9	8.5
Color filter 11	17	[40]	73.1	43	[40]	21.3	235	[40]	5.6	26.9

* In the table, the "[40]" means that the normalized variance was fixed to be 40% for convergence.

Examples 1 to 8

Electrodes corresponding to first and second substrates were formed, vertical alignment films were formed on the facing surfaces thereof, the alignment films were slightly rubbed to form a VA cell, and then a liquid crystal composition 1 shown in Table 2 was placed between the first and second substrates. Then, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 1 to 8 (d_{gap}=3.5 μm and alignment film SE-5300). The VHRs and ID of the produced liquid crystal display devices were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Table 3 shows results of the measurement and evaluation.

TABLE 2

Liquid crystal composition 1	
T_{NI}/° C.	81.0
Δn	0.103
Δε	−2.9
η/mPa · s	20.3
γ_1/mPa · s	112
$\gamma_1/\Delta n^2 \times 10^{-2}$	105
3-Cy-Cy-2	24%
3-Cy-Cy-4	10%
3-Cy-Cy-5	5%
3-Cy-Ph-O1	2%
3-Cy-Ph5-O2	13%
2-Cy-Ph-Ph5-O2	9%
3-Cy-Ph-Ph5-O2	9%
3-Cy-Cy-Ph5-O3	5%
4-Cy-Cy-Ph5-O2	6%
5-Cy-Cy-Ph5-O2	5%
3-Ph-Ph5-Ph-2	6%
4-Ph-Ph5-Ph-2	6%

In the liquid crystal composition 1, the temperature range of the liquid crystal phase was 81° C., which was practical for a liquid crystal composition used in TVs; in addition, the liquid crystal composition 1 had a dielectric anisotropy with a large absolute value, low viscosity, and proper Δn.

Each of the liquid crystal display devices of Examples 1 to 8 had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 9 to 24

As in Example 1, liquid crystal compositions shown in Table 4 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 9 to 24, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 5 and 6 show results of the measurement and evaluation.

TABLE 4

Liquid crystal composition 2		Liquid crystal composition 3	
T_{NI}/° C.	76.0	T_{NI}/° C.	84.8
Δn	0.103	Δn	0.103
Δε	−2.9	Δε	−2.9
η/mPa · s	19.8	η/mPa · s	21.4
γ_1/mPa · s	110	γ_1/mPa · s	119
$\gamma_1/\Delta n^2 \times 10^{-2}$	103	$\gamma_1/\Delta n^2 \times 10^{-2}$	112
3-Cy-Cy-2	24%	3-Cy-Cy-2	24%
3-Cy-Cy-4	10%	3-Cy-Cy-4	11%
3-Cy-Ph-O1	7%	3-Cy-Ph5-O2	12%

TABLE 3

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Liquid crystal composition	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1	Liquid crystal composition 1
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.4	99.6	99.5	99.2	99.5	99.6
ID	16	23	34	25	38	54	27	28
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 4-continued

Liquid crystal composition 2		Liquid crystal composition 3	
3-Cy-Ph5-O2	14%	2-Cy-Ph-Ph5-O2	5%
2-Cy-Ph-Ph5-O2	7%	3-Cy-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	9%	3-Cy-Cy-Ph5-O3	8%
3-Cy-Cy-Ph5-O3	5%	4-Cy-Cy-Ph5-O2	8%
4-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	8%
5-Cy-Cy-Ph5-O2	5%	3-Ph-Ph5-Ph-2	6%
3-Ph-Ph5-Ph-2	6%	4-Ph-Ph5-Ph-2	6%
4-Ph-Ph5-Ph-2	6%	5-Ph-Ph-1	3%
		3-Cy-Cy-Ph-1	3%

TABLE 5

	Example 9	Example 10	Example 11	Example 12	Example 13	Example 14	Example 15	Example 16
Liquid crystal composition	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2	Liquid crystal composition 2
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.5	99.5	99.6	99.4	99.3	99.4	99.5
ID	14	26	32	28	40	55	30	33
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 6

	Example 17	Example 18	Example 19	Example 20	Example 21	Example 22	Example 23	Example 24
Liquid crystal composition	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3	Liquid crystal composition 3
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.4	99.3	99.5	99.3	99.1	99.5	99.3
ID	19	33	42	30	44	61	36	34
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

The liquid crystal display devices of Examples 9 to 24 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 25 to 48

As in Example 1, liquid crystal compositions shown in Table 7 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 25 to 48, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 8 to 10 show results of the measurement and evaluation.

TABLE 7

Liquid crystal composition 4		Liquid crystal composition 5		Liquid crystal composition 6	
T_{NI}/° C.	74.9	T_{NI}/° C.	80.2	T_{NI}/° C.	85.7
Δn	0.102	Δn	0.105	Δn	0.104
Δε	−2.9	Δε	−2.9	Δε	−3.0
η/mPa · s	21.1	η/mPa · s	22.7	η/mPa · s	22.9
γ_1/mPa · s	116	γ_1/mPa · s	124	γ_1/mPa · s	126
$\gamma_1/\Delta n^2 \times 10^{-2}$	111	$\gamma_1/\Delta n^2 \times 10^{-2}$	112	$\gamma_1/\Delta n^2 \times 10^{-2}$	116
3-Cy-Cy-2	22%	3-Cy-Cy-2	20%	3-Cy-Cy-2	20%
3-Cy-Cy-4	11%	3-Cy-Cy-4	10%	3-Cy-Cy-4	10%

TABLE 7-continued

Liquid crystal composition 4		Liquid crystal composition 5		Liquid crystal composition 6	
3-Cy-Ph5-O2	7%	3-Cy-Ph5-O2	7%	3-Cy-Ph5-O2	7%
3-Cy-Ph5-O4	8%	3-Cy-Ph5-O4	7%	3-Cy-Ph5-O4	7%
2-Cy-Ph-Ph5-O2	6%	2-Cy-Ph-Ph5-O2	6%	2-Cy-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	7%	3-Cy-Ph-Ph5-O2	7%	3-Cy-Ph-Ph5-O2	7%
3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	7%
4-Cy Cy-Ph5-O2	7%	4-Cy-Cy-Ph5-O2	8%	4 Cy Cy-Ph5-O2	8%
5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%
3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%
5-Ph-Ph-1	8%	5-Ph-Ph-1	8%	5-Ph-Ph-1	5%
3-Cy-Cy-Ph-1	2%	3-Cy-Cy-Ph-1	5%	3-Cy-Cy-Ph-1	8%

TABLE 8

	Example 25	Example 26	Example 27	Example 28	Example 29	Example 30	Example 31	Example 32
Liquid crystal composition	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4	Liquid crystal composition 4
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.3	99.4	99.4	99.2	99.5	99.4
ID	15	36	45	38	41	66	39	42
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 9

	Example 33	Example 34	Example 35	Example 36	Example 37	Example 38	Example 39	Example 40
Liquid crystal composition	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5	Liquid crystal composition 5
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.5	99.4	99.5	99.4	99.3	99.3	99.4
ID	16	24	44	27	47	59	43	40
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Good	Excellent

TABLE 10

	Example 41	Example 42	Example 43	Example 44	Example 45	Example 46	Example 47	Example 48
Liquid crystal composition	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6	Liquid crystal composition 6
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.5	99.3	99.3	99.2	99.1	99.2	99.3
ID	18	28	46	39	50	68	47	38
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent

The liquid crystal display devices of Examples 25 to 48 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 49 to 72

As in Example 1, liquid crystal compositions shown in Table 11 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 49 to 72, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 12 to 14 show results of the measurement and evaluation.

TABLE 11

Liquid crystal composition 7		Liquid crystal composition 8		Liquid crystal composition 9	
T_{NI}/° C.	75.1	T_{NI}/° C.	80.4	T_{NI}/° C.	85.1
Δn	0.103	Δn	0.103	Δn	0.103
Δε	−2.6	Δε	−2.6	Δε	−2.6
η/mPa · s	20.5	n/mPa · s	21.6	η/mPa · s	22.7
γ_1/mPa · s	117	γ_1/mPa · s	125	γ_1/mPa · s	130
$\gamma_1/\Delta n^2 \times 10^{-2}$	110	$\gamma_1/\Delta n^2 \times 10^{-2}$	117	$\gamma_1/\Delta n^2 \times 10^{-2}$	122
3-Cy-Cy-2	15%	3-Cy-Cy-2	15%	3-Cy-Cy-2	10%
3-Cy-Cy-4	12%	3-Cy-Cy-4	12%	3-Cy-Cy-4	15%
3-Cy-Cy-5	7%	3-Cy-Cy-5	7%	3-Cy-Cy-5	12%
3-Cy-Ph-O1	12%	3-Cy-Ph-O1	12%	3-Cy-Ph-O1	9%
3-Cy-Ph5-O2	6%	3-Cy-Ph5-O2	5%	3-Cy-Ph5-O2	5%
3-Cy-Ph5-O4	7%	3-Cy-Ph5-O4	5%	3-Cy-Ph5-O4	5%
2-Cy-Ph-Ph5-O2	11%	2-Cy-Ph-Ph5-O2	11%	2-Cy-Ph-Ph5-O2	11%
3-Cy-Ph-Ph5-O2	12%	3-Cy-Ph-Ph5-O2	11%	3-Cy-Ph-Ph5-O2	11%
3-Cy-Cy-Ph5-O3	3%	3-Cy-Cy-Ph5-O3	4%	3-Cy-Cy-Ph5-O3	4%
4-Cy-Cy-Ph5-O2	4%	4-Cy-Cy-Ph5-O2	6%	4-Cy-Cy-Ph5-O2	6%
5-Cy-Cy-Ph5-O2	3%	5-Cy-Cy-Ph5-O2	4%	5-Cy-Cy-Ph5-O2	4%
3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%

TABLE 12

	Example 49	Example 50	Example 51	Example 52	Example 53	Example 54	Example 55	Example 56
Liquid crystal composition	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7	Liquid crystal composition 7
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.4	99.3	99.5	99.4	99.2	99.4	99.4
ID	19	40	48	37	49	67	32	31
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 13

	Example 57	Example 58	Example 59	Example 60	Example 61	Example 62	Example 63	Example 64
Liquid crystal composition	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8	Liquid crystal composition 8
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.5	99.5	99.6	99.4	99.3	99.5	99.5
ID	12	28	35	25	37	60	37	38
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 14

	Example 65	Example 66	Example 67	Example 68	Example 69	Example 70	Example 71	Example 72
Liquid crystal composition	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9	Liquid crystal composition 9
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.4	99.4	99.5	99.3	99.1	99.4	99.4
ID	24	34	44	31	46	69	35	37
Screen burn-in	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Good

The liquid crystal display devices of Examples 49 to 72 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 73 to 96

As in Example 1, liquid crystal compositions shown in Table 15 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 73 to 96, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 16 to 18 show results of the measurement and evaluation.

TABLE 15

Liquid crystal composition 10		Liquid crystal composition 11		Liquid crystal composition 12	
T_{NI}/° C.	76.7	T_{NI}/° C.	80.3	T_{NI}/° C.	85.8
Δn	0.109	Δn	0.105	Δn	0.104
Δε	−3.0	Δε	−3.1	Δε	−3.2
η/mPa · s	22.4	n/mPa · s	21.8	η/mPa · s	22.0
γ_1/mPa · s	131	γ_1/mPa · s	126	γ_1/mPa · s	128
$\gamma_1/\Delta n^2 \times 10^{-2}$	110	$\gamma_1/\Delta n^2 \times 10^{-2}$	114	$\gamma_1/\Delta n^2 \times 10^{-2}$	119
3-Cy-Cy-2	24%	3-Cy-Cy-2	24%	3-Cy-Cy-2	24%
3-Cy-Cy-4	6%	3-Cy-Cy-4	10%	3-Cy-Cy-4	10%
3-Cy-Ph-O1	5%	3-Cy-Ph-O1	4%	3-Cy-Ph-O1	4%
3-Cy-Ph5-O4	6%	3-Cy-Ph5-O4	6%	3-Cy-Ph5-O4	6%
3-Ph-Ph5-O2	6%	3-Ph-Ph5-O2	6%	3-Ph-Ph5-O2	6%
2-Cy-Ph-Ph5-O2	8%	2-Cy-Ph-Ph5-O2	8%	2-Cy-Ph-Ph5-O2	8%
3-Cy-Ph-Ph5-O2	8%	3-Cy-Ph-Ph5-O2	8%	3-Cy-Ph-Ph5-O2	8%
3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	7%
4-Cy-Cy-Ph5-O2	9%	4-Cy-Cy-Ph5-O2	9%	4-Cy-Cy-Ph5-O2	9%
5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%
3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%
5-Ph-Ph-1	6%	5-Ph-Ph-1	3%	3-Cy-Cy-Ph-1	3%

TABLE 16

	Example 73	Example 74	Example 75	Example 76	Example 77	Example 78	Example 79	Example 80
Liquid crystal composition	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10	Liquid crystal composition 10
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.3	99.5	99.4	99.2	99.4	99.4
ID	17	27	47	25	43	58	40	44
Screen burn-in	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent

TABLE 17

	Example 81	Example 82	Example 83	Example 84	Example 85	Example 86	Example 87	Example 88
Liquid crystal composition	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11	Liquid crystal composition 11
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.6	99.4	99.5	99.4	99.3	99.5	99.5
ID	16	25	39	30	43	55	34	32
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Good	Excellent

TABLE 18

	Example 89	Example 90	Example 91	Example 92	Example 93	Example 94	Example 95	Example 96
Liquid crystal composition	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12	Liquid crystal composition 12
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.8	99.6	99.5	99.6	99.5	99.3	99.4	99.5
ID	13	24	37	25	40	52	41	35
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

The liquid crystal display devices of Examples 73 to 96 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 97 to 120

As in Example 1, liquid crystal compositions shown in Table 19 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 97 to 120, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 20 to 22 show results of the measurement and evaluation.

TABLE 19

Liquid crystal composition 13		Liquid crystal composition 14		Liquid crystal composition 15	
T_{NI}/° C.	71.9	T_{NI}/° C.	78.8	T_{NI}/° C.	73.8
Δn	0.116	Δn	0.113	Δn	0.113
Δε	−3.6	Δε	−3.5	Δε	−3.9
η/mPa · s	21.2	n/mPa · s	21.1	η/mPa · s	21.8
γ_1/mPa · s	123	γ_1/mPa · s	122	γ_1/mPa · s	123
$\gamma_1/\Delta n^2 \times 10^{-2}$	92	$\gamma_1/\Delta n^2 \times 10^{-2}$	95	$\gamma_1/\Delta n^2 \times 10^{-2}$	97
3-Cy-Cy-2	24%	3-Cy-Cy-2	23%	3-Cy-Cy-2	16%
3-Cy-Ph-O1	7%	3-Cy-Cy-4	5%	3-Cy-Cy-4	9%
2-Cy-Ph5-O2	6%	3-Cy-Ph-O1	3%	3-Cy-Ph-O1	6%
3-Cy-Ph5-O4	6%	2-Cy-Ph5-O2	5%	2-Cy-Ph5-O2	6%
3-Ph-Ph5-O2	5%	3-Cy-Ph5-O4	5%	3-Cy-Ph5-O4	6%
5-Ph-Ph5-O2	5%	3-Ph-Ph5-O2	5%	3-Ph-Ph5-O2	6%
2-Cy-Ph-Ph5-O2	7%	5-Ph-Ph5-O2	5%	5-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	9%	2-Cy-Ph-Ph5-O2	7%	2-Cy-Ph-Ph5-O2	5%
3-Cy-Cy-Ph5-O3	5%	3-Cy-Ph-Ph5-O2	7%	3-Cy-Ph-Ph5-O2	7%
4-Cy-Cy-Ph5-O2	5%	3-Cy-Cy-Ph5-O3	5%	3-Cy-Cy-Ph5-O3	5%
5-Cy-Cy-Ph5-O2	4%	4-Cy-Cy-Ph5-O2	6%	4-Cy-Cy-Ph5-O2	6%
3-Ph-Ph5-Ph-2	5%	5-Cy-Cy-Ph5-O2	5%	5-Cy-Cy-Ph5-O2	6%
4-Ph-Ph5-Ph-2	6%	3-Ph-Ph5-Ph-2	5%	3-Ph-Ph5-Ph-2	5%
3-Cy-Cy-Ph-1	6%	4-Ph-Ph5-Ph-2	6%	4-Ph-Ph5-Ph-2	5%
		3-Cy-Cy-Ph-1	8%	3-Cy-Cy-Ph-1	6%

TABLE 20

	Example 97	Example 98	Example 99	Example 100	Example 101	Example 102	Example 103	Example 104
Liquid crystal composition	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13	Liquid crystal composition 13
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.3	99.5	99.4	99.1	99.3	99.4
ID	20	27	49	32	45	70	38	36
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Good

TABLE 21

	Example 105	Example 106	Example 107	Example 108	Example 109	Example 110	Example 111	Example 112
Liquid crystal composition	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14	Liquid crystal composition 14
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.4	99.3	99.4	99.3	99.2	99.4	99.5
ID	18	30	47	34	43	66	39	34
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

TABLE 22

	Example 113	Example 114	Example 115	Example 116	Example 117	Example 118	Example 119	Example 120
Liquid crystal composition	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15	Liquid crystal composition 15
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.6	99.4	99.5	99.4	99.2	99.4	99.5
ID	14	22	41	29	42	57	36	32
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

The liquid crystal display devices of Examples 97 to 120 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 121 to 144

As in Example 1, liquid crystal compositions shown in Table 23 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 121 to 144, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 24 to 26 show results of the measurement and evaluation.

TABLE 23

Liquid crystal composition 16		Liquid crystal composition 17		Liquid crystal composition 18	
T_{NI}/° C.	75.9	T_{NI}/° C.	82.3	T_{NI}/° C.	85.7
Δn	0.112	Δn	0.111	Δn	0.112
$\Delta\epsilon$	−2.8	$\Delta\epsilon$	−2.7	$\Delta\epsilon$	−2.8
η/mPa · s	19.8	η/mPa · s	19.2	η/mPa · s	20.1
γ_1/mPa · s	121	γ_1/mPa · s	114	γ_1/mPa · s	119
$\gamma_1/\Delta n^2 \times 10^{-2}$	96	$\gamma_1/\Delta n^2 \times 10^{-2}$	94	$\gamma_1/\Delta n^2 \times 10^{-2}$	95
3-Cy-Cy-2	19%	3-Cy-Cy-2	21%	3-Cy-Cy-2	19%
3-Cy-Cy-4	12%	3-Cy-Cy-4	12%	3-Cy-Cy-4	12%
3-Cy-Cy-5	5%	3-Cy-Cy-5	5%	3-Cy-Cy-5	4%
3-Cy-Ph-O1	5%	2-Cy-Ph5-O2	4%	2-Cy-Ph5-O2	4%
2-Cy-Ph5-O2	4%	3-Cy-Ph5-O4	4%	3-Cy-Ph5-O4	4%
3-Cy-Ph5-O4	4%	3-Ph-Ph5-O2	3%	3-Ph-Ph5-O2	3%
3-Ph-Ph5-O2	3%	5-Ph-Ph5-O2	4%	5-Ph-Ph5-O2	4%
5-Ph-Ph5-O2	4%	2-Cy-Ph-Ph5-O2	6%	2-Cy-Ph-Ph5-O2	6%

TABLE 23-continued

Liquid crystal composition 16		Liquid crystal composition 17		Liquid crystal composition 18	
2-Cy-Ph-Ph5-O2	6%	3-Cy-Ph-Ph5-O2	6%	3-Cy-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	6%	3-Cy-Cy-Ph5-O3	5%	3-Cy-Cy-Ph5-O3	5%
3-Cy-Cy-Ph5-O3	5%	4-Cy-Cy-Ph5-O2	5%	4-Cy-Cy-Ph5-O2	5%
4-Cy-Cy-Ph5-O2	5%	5-Cy-Cy-Ph5-O2	4%	5-Cy-Cy-Ph5-O2	4%
5-Cy-Cy-Ph5-O2	5%	3-Ph-Ph5-Ph-2	7%	3-Ph-Ph5-Ph-2	7%
3-Ph-Ph5-Ph-2	8%	4-Ph-Ph5-Ph-2	8%	4-Ph-Ph5-Ph-2	8%
4-Ph-Ph5-Ph-2	9%	3-Cy-Cy-Ph-1	6%	3-Cy-Cy-Ph-1	9%

TABLE 24

	Example 121	Example 122	Example 123	Example 124	Example 125	Example 126	Example 127	Example 128
Liquid crystal composition	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16	Liquid crystal composition 16
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.3	99.4	99.3	99.1	99.4	99.3
ID	19	25	54	38	55	63	37	33
Screen burn-in	Excellent	Excellent	Good	Excellent	Good	Good	Excellent	Excellent

TABLE 25

	Example 129	Example 130	Example 131	Example 132	Example 133	Example 134	Example 135	Example 136
Liquid crystal composition	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17	Liquid crystal composition 17
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.4	99.3	99.4	99.3	99.1	99.3	99.4
ID	23	35	55	37	54	70	44	41
Screen burn-in	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent

TABLE 26

	Example 137	Example 138	Example 139	Example 140	Example 141	Example 142	Example 143	Example 144
Liquid crystal composition	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18	Liquid crystal composition 18
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.6	99.4	99.6	99.5	99.2	99.5	99.6
ID	15	21	42	26	39	64	36	30
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

The liquid crystal display devices of Examples 121 to 144 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 145 to 168

As in Example 1, liquid crystal compositions shown in Table 27 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 145 to 168, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 28 to 30 show results of the measurement and evaluation.

TABLE 27

Liquid crystal composition 19		Liquid crystal composition 20		Liquid crystal composition 2	
T_{NI}/° C.	77.1	T_{NI}/° C.	82.7	T_{NI}/° C.	86.4
Δn	0.104	Δn	0.107	Δn	0.106
Δε	−3.5	Δε	−3.0	Δε	−3.0
η/mPa · s	25.1	η/mPa · s	24.2	η/mPa · s	24.4
γ_1/mPa · s	141	γ_1/mPa · s	141	γ_1/mPa · s	142
$\gamma_1/\Delta n^2 \times 10^{-2}$	131	$\gamma_1/\Delta n^2 \times 10^{-2}$	123	$\gamma_1/\Delta n^2 \times 10^{-2}$	126
3-Cy-Cy-2	22%	3-Cy-Cy-2	24%	3-Cy-Cy-2	24%
3-Cy-Ph-O1	14%	3-Cy-Cy-4	5%	3-Cy-Cy-4	5%
2-Cy-Ph5-O2	7%	3-Cy-Ph-O1	6%	3-Cy-Ph-O1	6%
3-Cy-Ph5-O4	8%	2-Cy-Ph5-O2	5%	2-Cy-Ph5-O2	5%
2-Cy-Ph-Ph5-O2	7%	3-Cy-Ph5-O4	5%	3-Cy-Ph5-O4	5%
3-Cy-Ph-Ph5-O2	9%	2-Cy-Ph-Ph5-O2	7%	2-Cy-Ph-Ph5-O2	7%
3-Cy-Cy-Ph5-O3	8%	3-Cy-Ph-Ph5-O2	9%	3-Cy-Ph-Ph5-O2	9%
4-Cy-Cy-Ph5-O2	8%	3-Cy-Cy-Ph5-O3	8%	3-Cy-Cy-Ph5-O3	8%
5-Cy-Cy-Ph5-O2	8%	4-Cy-Cy-Ph5-O2	8%	4-Cy-Cy-Ph5-O2	8%
3-Ph-Ph5-Ph-2	5%	5-Cy-Cy-Ph5-O2	8%	5-Cy-Cy-Ph5-O2	8%
4-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	5%	3-Ph-Ph5-Ph-2	5%
		4-Ph-Ph5-Ph-2	5%	4-Ph-Ph5-Ph-2	5%
		5-Ph-Ph-1	5%	5-Ph-Ph-1	3%
				3-Cy-Cy-Ph-1	2%

TABLE 28

	Example 145	Example 146	Example 147	Example 148	Example 149	Example 150	Example 151	Example 152
Liquid crystal composition	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19	Liquid crystal composition 19
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.4	99.5	99.4	99.2	99.4	99.5
ID	17	29	38	29	40	60	42	37
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 29

	Example 153	Example 154	Example 155	Example 156	Example 157	Example 158	Example 159	Example 160
Liquid crystal composition	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20	Liquid crystal composition 20
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.7	99.5	99.5	99.6	99.4	99.3	99.4	99.4
ID	14	31	37	27	42	56	40	40
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Good	Excellent

TABLE 30

	Example 161	Example 162	Example 163	Example 164	Example 165	Example 166	Example 167	Example 168
Liquid crystal composition	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21	Liquid crystal composition 21
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.5	99.3	99.4	99.3	99.1	99.4	99.5
ID	27	31	53	39	56	72	43	35
Screen burn-in	Excellent	Excellent	Good	Excellent	Good	Good	Excellent	Excellent

The liquid crystal display devices of Examples 145 to 168 each had a high VHR and small ID. In the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 169 to 192

As in Example 1, liquid crystal compositions shown in Table 31 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 169 to 192, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 32 to 34 show results of the measurement and evaluation.

TABLE 31

Liquid crystal composition 22		Liquid crystal composition 23		Liquid crystal composition 24	
T_{NI}/° C.	75.5	T_{NI}/° C.	80.3	T_{NI}/° C.	85.0
Δn	0.102	Δn	0.101	Δn	0.102
Δε	−2.8	Δε	−2.9	Δε	−3.0
η/mPa · s	22.2	η/mPa · s	22.0	η/mPa · s	22.7
γ_1/mPa · s	121	γ_1/mPa · s	118	γ_1/mPa · s	122
$\gamma_1/\Delta n^2 \times 10^{-2}$	117	$\gamma_1/\Delta n^2 \times 10^{-2}$	117	$\gamma_1/\Delta n^2 \times 10^{-2}$	118
3-Cy-Cy-2	14%	3-Cy-Cy-2	17%	3-Cy-Cy-2	16%
3-Cy-Cy-4	12%	3-Cy-Cy-4	12%	3-Cy-Cy-4	12%
3-Cy-Cy-5	5%	3-Cy-Cy-5	5%	3-Cy-Cy-5	5%
3-Cy-Ph-O1	7%	3-Cy-Ph-O1	6%	3-Cy-Ph-O1	5%
2-Cy-Ph5-O2	7%	2-Cy-Ph5-O2	12%	2-Cy-Ph5-O2	12%
3-Cy-Ph5-O4	7%	2-Cy-Ph-Ph5-O2	9%	2-Cy-Ph-Ph5-O2	9%
2-Cy-Ph-Ph5-O2	8%	3-Cy-Ph-Ph5-O2	9%	3-Cy-Ph-Ph5-O2	9%
3-Cy-Ph-Ph5-O2	8%	3-Cy-Cy-Ph5-O3	6%	3-Cy-Cy-Ph5-O3	6%
3-Cy-Cy-Ph5-O3	6%	4-Cy-Cy-Ph5-O2	8%	4-Cy-Cy-Ph5-O2	8%
4-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	6%	5-Cy-Cy-Ph5-O2	6%
5-Cy-Cy-Ph5-O2	6%	3-Ph-Ph5-Ph-2	3%	3-Ph-Ph5-Ph-2	3%
3-Ph-Ph5-Ph-2	3%	4-Ph-Ph5-Ph-2	3%	4-Ph-Ph5-Ph-2	3%
4-Ph-Ph5-Ph-2	3%	5-Ph-Ph-1	4%	5-Ph-Ph-1	3%
5-Ph-Ph-1	6%			3-Cy-Cy-Ph-1	3%
3-Cy-Cy-Ph-1	1%				

TABLE 32

	Example 169	Example 170	Example 171	Example 172	Example 173	Example 174	Example 175	Example 176
Liquid crystal composition	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22	Liquid crystal composition 22
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.6	99.4	99.5	99.4	99.2	99.4	99.5
ID	19	24	40	28	44	59	38	39
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 33

	Example 177	Example 178	Example 179	Example 180	Example 181	Example 182	Example 183	Example 184
Liquid crystal composition	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23	Liquid crystal composition 23
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.4	99.3	99.4	99.3	99.1	99.3	99.4
ID	25	32	50	36	56	75	46	43
Screen burn-in	Excellent	Excellent	Good	Excellent	Good	Good	Good	Excellent

TABLE 34

	Example 185	Example 186	Example 187	Example 188	Example 189	Example 190	Example 191	Example 192
Liquid crystal composition	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24	Liquid crystal composition 24
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.8	99.6	99.5	99.6	99.4	99.3	99.5	99.5
ID	13	20	31	22	35	49	32	32
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

The liquid crystal display devices of Examples 169 to 192 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 193 to 216

As in Example 1, liquid crystal compositions shown in Table 35 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 193 to 216, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 36 to 38 show results of the measurement and evaluation.

TABLE 35

Liquid crystal composition 25		Liquid crystal composition 26		Liquid crystal composition 27	
T_{NI}/° C.	75.6	T_{NI}/° C.	81.1	T_{NI}/° C.	85.7
Δn	0.104	Δn	0.105	Δn	0.105
$\Delta\epsilon$	−2.8	$\Delta\epsilon$	−2.8	$\Delta\epsilon$	−2.9
η/mPa · s	20.2	η/mPa · s	20.8	η/mPa · s	21.0
γ_1/mPa · s	117	γ_1/mPa · s	119	γ_1/mPa · s	92
$\gamma_1/\Delta n^2 \times 10^{-2}$	107	$\gamma_1/\Delta n^2 \times 10^{-2}$	107	$\gamma_1/\Delta n^2 \times 10^{-2}$	82
3-Cy-Cy-2	25%	3-Cy-Cy-2	25%	3-Cy-Cy-2	25%
3-Cy-Cy-4	10%	3-Cy-Cy-4	10%	3-Cy-Cy-4	12%
3-Cy-Ph-O1	4%	3-Cy-Ph-O1	4%	2-Cy-Ph5-O2	12%
2-Cy-Ph5-O2	7%	2-Cy-Ph5-O2	12%	2-Cy-Ph-Ph5-O2	5%
3-Cy-Ph5-O4	8%	2-Cy-Ph-Ph5-O2	5%	3-Cy-Ph-Ph5-O2	6%
2-Cy-Ph-Ph5-O2	5%	3-Cy-Ph-Ph5-O2	6%	3-Cy-Cy-Ph5-O3	7%
3-Cy-Ph-Ph5-O2	6%	3-Cy-Cy-Ph5-O3	7%	4-Cy-Cy-Ph5-O2	8%
3-Cy-Cy-Ph5-O3	6%	4-Cy-Cy-Ph5-O2	8%	5-Cy-Cy-Ph5-O2	7%
4-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%	3-Ph-Ph5-Ph-2	8%
5-Cy-Cy-Ph5-O2	6%	3-Ph-Ph5-Ph-2	8%	4-Ph-Ph5-Ph-2	8%
3-Ph-Ph5-Ph-2	8%	4-Ph-Ph5-Ph-2	8%	3-Cy-Cy-Ph-1	2%
4-Ph-Ph5-Ph-2	8%				

TABLE 36

	Example 193	Example 194	Example 195	Example 196	Example 197	Example 198	Example 199	Example 200
Liquid crystal composition	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25	Liquid crystal composition 25
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10

TABLE 36-continued

	Example 193	Example 194	Example 195	Example 196	Example 197	Example 198	Example 199	Example 200
VHR	99.7	99.6	99.5	99.5	99.4	99.2	99.4	99.4
ID	18	26	42	35	48	57	45	38
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent

TABLE 37

	Example 201	Example 202	Example 203	Example 204	Example 205	Example 206	Example 207	Example 208
Liquid crystal composition	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26	Liquid crystal composition 26
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.5	99.5	99.4	99.2	99.5	99.5
ID	21	34	39	33	46	70	35	38
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

TABLE 38

	Example 209	Example 210	Example 211	Example 212	Example 213	Example 214	Example 215	Example 216
Liquid crystal composition	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27	Liquid crystal composition 27
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.3	99.4	99.4	99.1	99.4	99.3
ID	19	29	33	25	42	78	37	42
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Good

The liquid crystal display devices of Examples 193 to 216 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 217 to 224

The liquid crystal composition 1 was mixed with 0.3 mass % of 2-methyl-acrylic acid 4-{2-[4-(2-acryloyloxy-ethyl)-phenoxycarbonyl]-ethyl}-biphenyl-4'-yl ester to produce a liquid crystal composition 28. The liquid crystal composition 28 was placed in the VA cell used in Example 1 and then polymerized by being irradiated with ultraviolet for 600 seconds (3.0 J/cm^2) while a driving voltage was applied between the electrodes. Then, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 217 to 224, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Table 39 shows results of the measurement and evaluation.

TABLE 39

	Example 217	Example 218	Example 219	Example 220	Example 221	Example 222	Example 223	Example 224
Liquid crystal composition	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28	Liquid crystal composition 28
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.5	99.4	99.4	99.4	99.0	99.3	99.4
ID	24	33	43	33	47	77	34	35
Screen burn-in	Excellent	Excellent	Good	Excellent	Good	Good	Excellent	Excellent

The liquid crystal display devices of Examples 217 to 224 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 225 to 232

The liquid crystal composition 13 was mixed with 0.3 mass % of bismethacrylic acid biphenyl-4,4'-diyl ester to produce a liquid crystal composition 29. The liquid crystal composition 29 was placed in the VA cell used in Example 1 and then polymerized by being irradiated with ultraviolet for 600 seconds (3.0 J/cm^2) while a driving voltage was applied between the electrodes. Then, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 225 to 232, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Table 40 shows results of the measurement and evaluation.

TABLE 40

	Example 225	Example 226	Example 227	Example 228	Example 229	Example 230	Example 231	Example 232
Liquid crystal composition	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29	Liquid crystal composition 29
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.4	99.3	99.5	99.3	99.1	99.3	99.3
ID	30	43	50	39	54	73	52	44
Screen burn-in	Excellent	Excellent	Good	Excellent	Good	Good	Good	Excellent

The liquid crystal display devices of Examples 225 to 232 each had a high VHR and small ID. In the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 233 to 240

The liquid crystal composition 19 was mixed with 0.3 mass % of bismethacrylic acid 3-fluorobiphenyl-4,4'-diyl ester to produce a liquid crystal composition 30. The liquid crystal composition 30 was placed in the VA cell used in Example 1 and then polymerized by being irradiated with ultraviolet for 600 seconds (3.0 J/cm^2) while a driving voltage was applied between the electrodes. Then, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 233 to 240, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Table 41 shows results of the measurement and evaluation.

TABLE 41

	Example 233	Example 234	Example 235	Example 236	Example 237	Example 238	Example 239	Example 240
Liquid crystal composition	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30	Liquid crystal composition 30
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.5	99.4	99.5	99.4	99.2	99.4	99.5
ID	22	32	45	37	44	69	33	35
Screen burn-in	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent

The liquid crystal display devices of Examples 233 to 240 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Comparative Examples 1 to 24

As in Example 1, comparative liquid crystal compositions shown in Table 42 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 1 to 24, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 43 to 45 show results of the measurement and evaluation.

TABLE 42

Comparative liquid crystal composition 1		Comparative liquid crystal composition 2		Comparative liquid crystal composition 3	
T_{NI}/° C.	75.5	T_{NI}/° C.	80.7	T_{NI}/° C.	85.8
Δn	0.104	Δn	0.104	Δn	0.104
Δε	−2.88	Δε	−2.88	Δε	−2.95
η/mPa · s	22.5	η/mPa · s	22.3	η/mPa · s	22.4
γ_1/mPa · s	123	γ_1/mPa · s	122	γ_1/mPa · s	124
$\gamma_1/\Delta n^2 \times 10^{-2}$	114	$\gamma_1/\Delta n^2 \times 10^{-2}$	113	$\gamma_1/\Delta n^2 \times 10^{-2}$	114
3-Cy-Cy-2	24%	3-Cy-Cy-2	24%	3-Cy-Cy-2	24%
3-Cy-Cy-4	4%	3-Cy-Cy-4	4%	3-Cy-Cy-4	4%
3-Cy-Ph5-O2	7%	3-Cy-Ph5-O2	7%	3-Cy-Ph5-O2	7%
3-Cy-Ph5-O4	8%	3-Cy-Ph5-O4	8%	3-Cy-Ph5-O4	8%
2-Cy-Ph-Ph5-O2	4%	2-Cy-Ph-Ph5-O2	5%	2-Cy-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	5%	3-Cy-Ph-Ph5-O2	6%	3-Cy-Ph-Ph5-O2	7%
3-Cy-Cy-Ph5-O3	8%	3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	7%
4-Cy-Cy-Ph5-O2	10%	4-Cy-Cy-Ph5-O2	9%	4-Cy-Cy-Ph5-O2	7%
5-Cy-Cy-Ph5-O2	8%	5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	7%
3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%
5-Ph-Ph-1	10%	5-Ph-Ph-1	7%	5-Ph-Ph-1	4%
3-Cy-Cy-Ph-1	4%	3-Cy-Cy-Ph-1	8%	3-Cy-Cy-Ph-1	11%

TABLE 43

	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8
Liquid crystal composition	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1	Comparative liquid crystal composition 1
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.3	98.1	97.7	98.2	97.7	97.3	98.0	98.1
ID	145	165	187	159	182	212	178	168
Screen burn-in	Bad	Poor	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 44

	Comparative Example 9	Comparative Example 10	Comparative Example 11	Comparative Example 12	Comparative Example 13	Comparative Example 14	Comparative Example 15	Comparative Example 16
Liquid crystal composition	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2	Comparative liquid crystal composition 2
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.2	97.5	98.2	97.6	97.3	98.1	98.2
ID	140	168	190	155	183	210	172	164
Screen burn-in	Bad	Poor	Poor	Bad	Poor	Poor	Poor	Poor

TABLE 45

	Comparative Example 17	Comparative Example 18	Comparative Example 19	Comparative Example 20	Comparative Example 21	Comparative Example 22	Comparative Example 23	Comparative Example 24
Liquid crystal composition	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3	Comparative liquid crystal composition 3
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.0	97.5	98.1	97.5	97.2	97.9	98.0
ID	143	170	189	164	186	217	176	165
Screen burn-in	Bad	Poor	Poor	Bad	Poor	Poor	Poor	Bad

Each of the liquid crystal display devices of Comparative Examples 1 to 24 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Moreover, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 25 to 48

As in Example 1, comparative liquid crystal compositions shown in Table 46 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 25 to 48, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 47 to 49 show results of the measurement and evaluation.

TABLE 46

Comparative liquid crystal composition 4		Comparative liquid crystal composition 5		Comparative liquid crystal composition 6	
T_{NI}/° C.	73.6	T_{NI}/° C.	80.9	T_{NI}/° C.	84.7
Δn	0.099	Δn	0.094	Δn	0.085
$\Delta\epsilon$	−2.15	$\Delta\epsilon$	−2.16	$\Delta\epsilon$	−2.13
η/ mPa · s	17.7	η/mPa · s	17.0	η/mPa · s	17.5
γ_1/mPa · s	104	γ_1/mPa · s	97	γ_1/mPa · s	98
$\gamma_1/\Delta n^2 \times 10^{-2}$	106	$\gamma_1/\Delta n^2 \times 10^{-2}$	109	$\gamma_1/\Delta n^2 \times 10^{-2}$	136
3-Cy-Cy-2	20%	3-Cy-Cy-2	24%	3-Cy-Cy-2	21%
3-Cy-Cy-4	12%	3-Cy-Cy-4	12%	3-Cy-Cy-4	15%
3-Cy-Cy-5	7%	3-Cy-Cy-5	15%	3-Cy-Cy-5	15%
3-Cy-Ph-O1	12%	3-Cy-Ph5-O2	5%	3-Cy-Ph5-O2	5%
3-Cy-Ph5-O2	5%	3-Cy-Ph5-O4	5%	3-Cy-Ph5-O4	5%
3-Cy-Ph5-O4	5%	2-Cy-Ph-Ph5-O2	11%	2-Cy-Ph-Ph5-O2	4%
2-Cy-Ph-Ph5-O2	11%	3-Cy-Ph-Ph5-O2	11%	3-Cy-Ph-Ph5-O2	5%
3-Cy-Ph-Ph5-O2	11%	3-Cy-Cy-Ph5-O3	3%	3-Cy-Cy-Ph5-O3	7%
3-Cy-Cy-Ph5-O3	3%	4-Cy-Cy-Ph5-O2	3%	4-Cy-Cy-Ph5-O2	8%
4-Cy-Cy-Ph5-O2	3%	5-Cy-Cy-Ph5-O2	3%	5-Cy-Cy-Ph5-O2	7%
5-Cy-Cy-Ph5-O2	3%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
3-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%				

TABLE 47

	Comparative Example 25	Comparative Example 26	Comparative Example 27	Comparative Example 28	Comparative Example 29	Comparative Example 30	Comparative Example 31	Comparative Example 32
Liquid crystal composition	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4	Comparative liquid crystal composition 4
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.3	98.1	97.4	98.1	97.4	97.1	97.8	98.0
ID	146	161	190	162	191	222	179	167
Screen burn-in	Bad	Bad	Poor	Bad	Poor	Poor	Poor	Poor

TABLE 48

	Comparative Example 33	Comparative Example 34	Comparative Example 35	Comparative Example 36	Comparative Example 37	Comparative Example 38	Comparative Example 39	Comparative Example 40
Liquid crystal composition	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5	Comparative liquid crystal composition 5
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.5	98.4	98.0	98.3	97.9	97.5	98.1	98.1
ID	133	151	180	153	182	203	174	175
Screen burn-in	Bad	Poor	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 49

	Comparative Example 41	Comparative Example 42	Comparative Example 43	Comparative Example 44	Comparative Example 45	Comparative Example 46	Comparative Example 47	Comparative Example 48
Liquid crystal composition	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6	Comparative liquid crystal composition 6
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.5	98.3	97.9	98.2	97.8	97.4	98.0	98.1
ID	130	147	177	149	180	207	171	178
Screen burn-in	Bad	Bad	Poor	Poor	Poor	Poor	Poor	Poor

Each of the liquid crystal display devices of Comparative Examples 25 to 48 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Moreover, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 49 to 72

As in Example 1, comparative liquid crystal compositions shown in Table 50 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 49 to 72, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 51 to 53 show results of the measurement and evaluation.

TABLE 50

Comparative liquid crystal composition 7		Comparative liquid crystal composition 8		Comparative liquid crystal composition 9	
T_{NI}/° C.	77.1	T_{NI}/° C.	80.8	T_{NI}/° C.	86.3
Δn	0.109	Δn	0.108	Δn	0.107
Δε	−2.10	Δε	−2.20	Δε	−2.27
η/mPa · s	21.6	η/mPa · s	22.1	η/mPa · s	22.3
γ_1/mPa · s	130	γ_1/mPa · s	133	γ_1/mPa · s	134
$\gamma_1/\Delta n^2 \times 10^{-2}$	109	$\gamma_1/\Delta n^2 \times 10^{-2}$	114	$\gamma_1/\Delta n^2 \times 10^{-2}$	118
3-Cy-Cy-2	24%	3-Cy-Cy-2	24%	3-Cy-Cy-2	24%
3-Cy-Cy-4	7%	3-Cy-Cy-4	7%	3-Cy-Cy-4	7%
3-Cy-Ph-O1	5%	3-Cy-Ph-O1	5%	3-Cy-Ph-O1	5%
2-Cy-Ph5-O2	2%	2-Cy-Ph5-O2	2%	2-Cy-Ph5-O2	2%
3-Cy-Ph5-O4	2%	3-Cy-Ph5-O4	2%	3-Cy-Ph5-O4	2%
2-Cy-Ph-Ph5-O2	8%	2-Cy-Ph-Ph5-O2	8%	2-Cy-Ph-Ph5-O2	8%
3-Cy-Ph-Ph5-O2	8%	3-Cy-Ph-Ph5-O2	8%	3-Cy-Ph-Ph5-O2	8%
3-Cy-Cy-Ph5-O3	7%	3-Cy-Cy-Ph5-O3	8%	3-Cy-Cy-Ph5-O3	8%
4-Cy-Cy-Ph5-O2	9%	4-Cy-Cy-Ph5-O2	8%	4-Cy-Cy-Ph5-O2	8%
5-Cy-Cy-Ph5-O2	7%	5-Cy-Cy-Ph5-O2	8%	5-Cy-Cy-Ph5-O2	8%
3-Ph-Ph5-Ph2	4%	3-Ph-Ph5-Ph-2	4%	3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%	4-Ph-Ph5-Ph-2	4%
5-Ph-Ph-1	13%	5-Ph-Ph-1	11%	5-Ph-Ph-1	8%
		3-Cy-Cy-Ph-1	1%	3-Cy-Cy-Ph-1	4%

TABLE 51

	Comparative Example 49	Comparative Example 50	Comparative Example 51	Comparative Example 52	Comparative Example 53	Comparative Example 54	Comparative Example 55	Comparative Example 56
Liquid crystal composition	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7	Comparative liquid crystal composition 7
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.4	97.9	98.3	97.7	97.5	98.1	98.3
ID	139	155	172	159	177	198	152	150
Screen burn-in	Bad	Poor	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 52

	Comparative Example 57	Comparative Example 58	Comparative Example 59	Comparative Example 60	Comparative Example 61	Comparative Example 62	Comparative Example 63	Comparative Example 64
Liquid crystal composition	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8	Comparative liquid crystal composition 8
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.6	98.4	98.1	98.4	97.8	97.6	98.3	98.4
ID	129	144	166	143	168	183	158	154
Screen burn-in	Bad	Bad	Poor	Bad	Poor	Poor	Poor	Poor

TABLE 53

	Comparative Example 65	Comparative Example 66	Comparative Example 67	Comparative Example 68	Comparative Example 69	Comparative Example 70	Comparative Example 71	Comparative Example 72
Liquid crystal composition	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9	Comparative liquid crystal composition 9
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.3	97.8	98.2	97.9	97.2	98.2	98.3
ID	144	152	186	158	184	214	159	150
Screen burn-in	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Each of the liquid crystal display devices of Comparative Examples 49 to 72 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Moreover, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 73 to 88

As in Example 1, comparative liquid crystal compositions shown in Table 54 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 73 to 88, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 55 and 56 show results of the measurement and evaluation.

TABLE 54

Comparative liquid crystal composition 10		Comparative liquid crystal composition 11	
T_{NI}/° C.	62.2	T_{NI}/° C.	72.4
Δn	0.087	Δn	0.088

TABLE 54-continued

Comparative liquid crystal composition 10		Comparative liquid crystal composition 11	
Δε	−4.1	Δε	−4.2
η/mPa · s	21.3	η/mPa · s	23.8
γ_1/mPa · s	97	γ_1/mPa · s	106
$\gamma_1/\Delta n^2 \times 10^{-2}$	129	$\gamma_1/\Delta n^2 \times 10^{-2}$	138
3-Cy-Cy-2	12%	3-Cy-Cy-4	20%
3-Cy-Cy-4	12%	3-Cy-Cy-5	15%
3-Cy-Cy-5	5%	2-Cy-Ph5-O2	16%
3-Cy-Ph-O1	6%	3-Cy-Ph5-O4	16%
2-Cy-Ph5-O2	16%	2-Cy-Ph-Ph5-O2	7%
3-Cy-Ph5-O4	16%	3-Cy-Ph-Ph5-O2	8%
2-Cy-Ph-Ph5-O2	7%	3-Cy-Cy-Ph5-O3	5%
3-Cy-Ph-Ph5-O2	8%	4-Cy-Cy-Ph5-O2	5%
3-Cy-Cy-Ph5-O3	5%	5-Cy-Cy-Ph5-O2	5%
4-Cy-Cy-Ph5-O2	5%	3-Cy-Cy-Ph-1	3%
5-Cy-Cy-Ph5-O2	5%		
3-Cy-Cy-Ph-1	3%		

TABLE 55

	Comparative Example 73	Comparative Example 74	Comparative Example 75	Comparative Example 76	Comparative Example 77	Comparative Example 78	Comparative Example 79	Comparative Example 80
Liquid crystal composition	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10	Comparative liquid crystal composition 10
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 6	Color filter 6
VHR	98.3	98.2	97.9	98.2	97.7	97.4	97.8	97.9
ID	149	157	174	156	179	210	183	176
Screen burn-in	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 56

	Comparative Example 81	Comparative Example 82	Comparative Example 83	Comparative Example 84	Comparative Example 85	Comparative Example 86	Comparative Example 87	Comparative Example 88
Liquid crystal composition	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11	Comparative liquid crystal composition 11
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.2	97.7	98.3	97.8	97.3	98.1	98.3
ID	143	167	180	168	179	203	175	162
Screen burn-in	Bad	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Each of the liquid crystal display devices of Comparative Examples 73 to 88 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Moreover, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 89 to 112

As in Example 1, comparative liquid crystal compositions shown in Table 57 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 89 to 112, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 58 to 60 show results of the measurement and evaluation.

TABLE 57

Comparative liquid crystal composition 12		Comparative liquid crystal composition 13		Comparative liquid crystal composition 14	
T_{NI}/° C.	74.9	T_{NI}/° C.	79.6	T_{NI}/° C.	85.4
Δn	0.103	Δn	0.104	Δn	0.107
$\Delta\epsilon$	−2.34	$\Delta\epsilon$	−2.39	$\Delta\epsilon$	−2.46
η/mPa · s	18.4	η/mPa · s	18.9	η/mPa · s	20.0
γ_1/mPa · s	106	γ_1/mPa · s	108	γ_1/mPa · s	114
$\gamma_1/\Delta n^2 \times 10^{-2}$	99	$\gamma_1/\Delta n^2 \times 10^{-2}$	99	$\gamma_1/\Delta n^2 \times 10^{-2}$	99
3-Cy-Cy-2	20%	3-Cy-Cy-2	20%	3-Cy-Cy-2	18%
3-Cy-Cy-4	12%	3-Cy-Cy-4	12%	3-Cy-Cy-4	12%
3-Cy-Cy-5	5%	3-Cy-Cy-5	5%	3-Cy-Cy-5	5%
3-Cy-Ph-O1	5%	3-Cy-Ph-O1	2%	2-Cy-Ph5-O2	7%
2-Cy-Ph5-O2	7%	2-Cy-Ph5-O2	7%	3-Cy-Ph5-O4	8%
3-Cy-Ph5-O4	8%	3-Cy-Ph5-O4	8%	2-Cy-Ph-Ph5-O2	6%
2-Cy-Ph-Ph5-O2	6%	2-Cy-Ph-Ph5-O2	6%	3-Cy-Ph-Ph5-O2	6%
3-Cy-Ph-Ph5-O2	6%	3-Cy-Ph-Ph5-O2	6%	3-Cy-Cy-Ph5-O3	4%
3-Cy-Cy-Ph5-O3	4%	3-Cy-Cy-Ph5-O3	4%	4-Cy-Cy-Ph5-O2	4%
4-Cy-Cy-Ph5-O2	4%	4-Cy-Cy-Ph5-O2	4%	5-Cy-Cy-Ph5-O2	4%
5-Cy-Cy-Ph5-O2	4%	5-Cy-Cy-Ph5-O2	4%	3-Ph-Ph5-Ph-2	7%
3-Ph-Ph5-Ph-2	7%	3-Ph-Ph5-Ph-2	7%	4-Ph-Ph5-Ph-2	8%
4-Ph-Ph5-Ph-2	8%	4-Ph-Ph5-Ph-2	8%	3-Cy-Cy-Ph-1	11%
3-Cy-Cy-Ph-1	4%	3-Cy-Cy-Ph-1	7%		

TABLE 58

	Comparative Example 89	Comparative Example 90	Comparative Example 91	Comparative Example 92	Comparative Example 93	Comparative Example 94	Comparative Example 95	Comparative Example 96
Liquid crystal composition	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12	Comparative liquid crystal composition 12
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.3	98.2	97.7	98.1	97.9	97.5	98.0	98.2
ID	151	167	202	172	189	225	180	170
Screen burn-in	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 59

	Comparative Example 97	Comparative Example 98	Comparative Example 99	Comparative Example 100	Comparative Example 101	Comparative Example 102	Comparative Example 103	Comparative Example 104
Liquid crystal composition	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13	Comparative liquid crystal composition 13
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.4	98.2	97.8	98.2	97.6	97.4	98.1	98.3
ID	140	162	177	165	184	208	169	157
Screen burn-in	Bad	Bad	Poor	Poor	Poor	Poor	Poor	Poor

TABLE 60

	Comparative Example 105	Comparative Example 106	Comparative Example 107	Comparative Example 108	Comparative Example 109	Comparative Example 110	Comparative Example 111	Comparative Example 112
Liquid crystal composition	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14	Comparative liquid crystal composition 14
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.5	98.4	97.8	98.4	97.9	97.6	98.4	98.4
ID	132	148	183	150	185	192	152	146
Screen burn-in	Bad	Bad	Poor	Poor	Poor	Poor	Poor	Bad

Each of the liquid crystal display devices of Comparative Examples 89 to 112 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Furthermore, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 113 to 120

As in Example 1, a comparative liquid crystal composition shown in Table 61 was placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 113 to 120, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Table 62 shows results of the measurement and evaluation.

TABLE 61

	Comparative liquid crystal composition 15
T_{NI}/° C.	86.3
Δn	0.105
Δε	−3.41
η/mPa · s	26.4
γ_1/mPa · s	149
$\gamma_1/\Delta n^2 \times 10^{-2}$	135
3-Cy-Cy-2	24%
3-Cy-Ph-O1	11%
2-Cy-Ph5-O2	10%
2-Cy-Ph-Ph5-O2	7%
3-Cy-Ph-Ph5-O2	9%
3-Cy-Cy-Ph5-O3	10%
4-Cy-Cy-Ph5-O2	10%
5-Cy-Cy-Ph5-O2	10%
3-Ph-Ph5-Ph-2	4%
4-Ph-Ph5-Ph-2	4%
5-Ph-Ph-1	1%

TABLE 62

	Comparative Example 113	Comparative Example 114	Comparative Example 115	Comparative Example 116	Comparative Example 117	Comparative Example 118	Comparative Example 119	Comparative Example 120
Liquid crystal composition	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15	Comparative liquid crystal composition 15
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	98.3	98.1	97.6	98.1	97.7	97.3	97.9	98.0
ID	150	169	188	164	185	212	173	166
Screen burn-in	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Each of the liquid crystal display devices of Comparative Examples 113 to 120 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Furthermore, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Comparative Examples 121 to 144

The liquid crystal compositions 1, 2, 8, 13, 14, 19, 20, and 26 were individually placed in the VA cell used in Example 1; the color filters 7, 9, and 11 shown in Table 1 were used to produce liquid crystal display devices of Comparative Examples 121 to 144; and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 63 to 65 show results of the measurement and evaluation.

TABLE 63

	Comparative Example 121	Comparative Example 122	Comparative Example 123	Comparative Example 124	Comparative Example 125	Comparative Example 126	Comparative Example 127	Comparative Example 128
Liquid crystal composition	Liquid crystal composition 1	Liquid crystal composition 2	Liquid crystal composition 8	Liquid crystal composition 13	Liquid crystal composition 14	Liquid crystal composition 19	Liquid crystal composition 20	Liquid crystal composition 26
Color filter	Color filter 7	Color filter 7	Color filter 7	Color filter 7	Color filter 7	Color filter 7	Color filter 7	Color filter 7
VHR	98.6	98.7	98.6	98.4	98.5	98.5	98.6	98.5
ID	101	105	107	130	117	112	108	122
Screen burn-in	Bad	Poor	Bad	Poor	Poor	Poor	Bad	Poor

TABLE 64

	Comparative Example 129	Comparative Example 130	Comparative Example 131	Comparative Example 132	Comparative Example 133	Comparative Example 134	Comparative Example 135	Comparative Example 136
Liquid crystal composition	Liquid crystal composition 1	Liquid crystal composition 2	Liquid crystal composition 8	Liquid crystal composition 13	Liquid crystal composition 14	Liquid crystal composition 19	Liquid crystal composition 20	Liquid crystal composition 26
Color filter	Color filter 9	Color filter 9	Color filter 9	Color filter 9	Color filter 9	Color filter 9	Color filter 9	Color filter 9
VHR	98.5	98.4	98.5	98.2	98.4	98.3	98.2	98.2
ID	140	145	136	162	132	154	155	144
Screen burn-in	Poor	Poor	Bad	Poor	Bad	Poor	Poor	Bad

TABLE 65

	Comparative Example 137	Comparative Example 138	Comparative Example 139	Comparative Example 140	Comparative Example 141	Comparative Example 142	Comparative Example 143	Comparative Example 144
Liquid crystal composition	Liquid crystal composition 1	Liquid crystal composition 2	Liquid crystal composition 8	Liquid crystal composition 13	Liquid crystal composition 14	Liquid crystal composition 19	Liquid crystal composition 20	Liquid crystal composition 26
Color filter	Color filter 11	Color filter 11	Color filter 11	Color filter 11	Color filter 11	Color filter 11	Color filter 11	Color filter 11
VHR	98.5	98.6	98.4	98.4	98.3	98.3	98.4	98.3
ID	116	123	128	139	157	150	141	131
Screen burn-in	Bad	Bad	Bad	Poor	Poor	Poor	Poor	Poor

Each of the liquid crystal display devices of Comparative Examples 121 to 144 had a lower VHR and larger ID than the liquid crystal display device of the present invention. Moreover, in the evaluation of screen burn-in, an unacceptable degree of afterimage was observed.

Examples 241 to 264

As in Example 1, liquid crystal compositions shown in Table 66 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 241 to 264, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 67 to 69 show results of the measurement and evaluation.

TABLE 66

Liquid crystal composition 31		Liquid crystal composition 32		Liquid crystal composition 33	
TNI/° C.	75.5	TNI/° C.	75.4	TNI/° C.	83.1
Δn	0.103	Δn	0.109	Δn	0.114
Δε	−3.1	Δε	−3.1	Δε	−2.9
η/mPa · s	15.8	η/mPa · s	14.9	η/mPa · s	14.8
γ1/mPa · s	113	γ1/mPa · s	110	γ1/mPa · s	92
γ1/Δn2 × 10−2	113	γ1/Δn2 × 10−2	92	γ1/Δn2 × 10−2	71
3-Cy-Cy-2	13%	2-Cy-Cy-V1	20%	V2-Ph-Ph-1	5%
3-Cy-Cy-V1	12%	3-Cy-Cy-V1	13%	3-Cy-Cy-V	39%
3-Cy-Cy-4	5%	3-Ph-Ph-1	10%	3-Cy-1O-Ph5-O2	5%
3-Ph-Ph-1	3%	5-Ph-Ph-1	5%	2-Cy-Cy-1O-Ph5-O2	11%
5-Ph-Ph-1	12%	3-Cy-Ph-Ph-2	6%	3-Cy-Cy-1O-Ph5-O1	11%
3-Cy-Cy-Ph-1	3%	1V-Cy-1O-Ph5-O2	8%	3-Cy-Cy-1O-Ph5-O2	6%
V-Cy-Ph-Ph-3	6%	2-Cy-Cy-1O-Ph5-O2	10%	2-Cy-Ph-Ph5-O2	6%
3-Cy-1O-Ph5-O2	11%	3-Cy-Cy-1O-Ph5-O2	10%	3-Ph-Ph5-Ph-1	8%
2-Cy-Cy-1O-Ph5-O2	12%	V-Cy-Cy-1O-Ph5-O2	10%	3-Ph-Ph5-Ph-2	9%
3-Cy-Cy-1O-Ph5-O2	12%	1V-Cy-Cy-1O-Ph5-O2	4%		
4-Cy-Cy-1O-Ph5-O2	2%	3-Ph-Ph5-Ph-2	4%		
V-Cy-Cy-1O-Ph5-O2	3%				
1V-Cy-Cy-1O-Ph5-O2	6%				

TABLE 67

	Example 241	Example 242	Example 243	Example 244	Example 245	Example 246	Example 247	Example 248
Liquid crystal composition	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31	Liquid crystal composition 31
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.6	99.4	99.3	99.4	99.2	99.1	99.3	99.5
ID	17	35	46	38	54	76	38	30
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

TABLE 68

	Example 249	Example 250	Example 251	Example 252	Example 253	Example 254	Example 255	Example 256
Liquid crystal composition	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32	Liquid crystal composition 32
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.5	99.2	99.4	99.3	99.1	99.4	99.4
ID	32	40	53	35	48	72	43	39
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent

TABLE 69

	Example 257	Example 258	Example 259	Example 260	Example 261	Example 262	Example 263	Example 264
Liquid crystal composition	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33	Liquid crystal composition 33
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.4	99.3	99.2	99.4	99.1	99.0	99.2	99.3
ID	34	44	52	40	57	76	55	43
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

The liquid crystal display devices of Examples 241 to 264 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

Examples 265 to 280

As in Example 1, liquid crystal compositions shown in Table 70 were individually placed between the substrates, the color filters 1 to 6, 8, and 10 shown in Table 1 were used to produce liquid crystal display devices of Examples 265 to 280, and the VHRs and ID thereof were measured. The liquid crystal display devices were subjected to the evaluation of screen burn-in. Tables 71 and 72 show results of the measurement and evaluation.

[Table 70]

Liquid crystal composition 34		Liquid crystal composition 35	
TNI/° C.	76.3	TNI/° C.	76.6
Δn	0.106	Δn	0.109
Δε	−3.0	Δε	−3.2
η/mPa · s	16.6	η/mPa · s	13.9
γ1/mPa · s	106	γ1/mPa · s	95
γ1/Δn2 × 10−2	95	γ1/Δn2 × 10−2	80
3-Cy-Cy-2	17%	1V-Cy-1O-Ph5-O2	12%
3-Cy-Ph-Ph-2	12%	1V-Cy-Cy-1O-Ph5-O2	12%
3-Cy-1O-Ph5-O1	11%	3-Cy-1O-Ph5-O2	2%
3-Cy-1O-Ph5-O2	17%	2-Cy-Cy-1O-Ph5-O2	5%
3-Nd-Ph5-Ph-2	4%	3-Cy-Cy-1O-Ph5-O2	4%
3-Cy-Cy-V	5%	3-Cy-Ph-Ph5-O2	4%
3-Cy-Cy-V1	10%	3-Cy-Cy-V	38%
V-Cy-Ph-Ph-3	12%	3-Cy-Cy-V1	3%
V-Cy-Cy-1O-Ph5-O3	12%	3-Ph-Ph-1	3%
		V2-Ph-Ph5-Ph-2V	12%
		1V2-Ph-Ph5-Ph2-V1	5%

TABLE 71

	Example 265	Example 266	Example 267	Example 268	Example 269	Example 270	Example 271	Example 272
Liquid crystal composition	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34	Liquid crystal composition 34
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.5	99.4	99.2	99.4	99.2	99.0	99.3	99.4
ID	29	38	56	41	58	78	52	36
Screen burn-in	Excellent	Excellent	Good	Excellent	Excellent	Good	Good	Excellent

TABLE 72

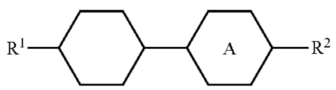
	Example 273	Example 274	Example 275	Example 276	Example 277	Example 278	Example 279	Example 280
Liquid crystal composition	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35	Liquid crystal composition 35
Color filter	Color filter 1	Color filter 2	Color filter 3	Color filter 4	Color filter 5	Color filter 6	Color filter 8	Color filter 10
VHR	99.4	99.3	99.2	99.3	99.1	99.1	99.2	99.3
ID	33	42	55	45	52	77	48	41
Screen burn-in	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent

The liquid crystal display devices of Examples 265 to 280 each had a high VHR and small ID. Furthermore, in the evaluation of screen burn-in, no afterimage was observed, or an acceptable degree of slight afterimage was observed, if any.

The invention claimed is:

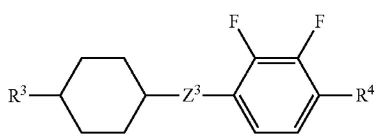
1. A liquid crystal display device comprising a first substrate, a second substrate, a liquid crystal composition layer disposed between the first substrate and the second substrate, a color filter including a black matrix and at least RGB three-color pixels, a pixel electrode, and a common electrode, wherein

the liquid crystal composition layer contains a liquid crystal composition containing a compound represented by General Formula (I) in an amount of 30 to 50%



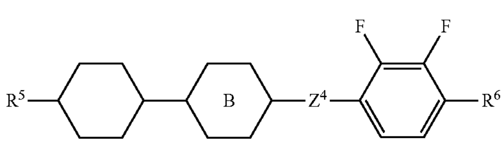
(I)

(where R^1 and R^2 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; and A represents a 1,4-phenylene group or a trans-1,4-cyclohexylene group), a compound represented by General Formula (II-1) in an amount of 5 to 30%



(II-1)

(where R^3 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^4 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; and Z^3 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—), and a compound represented by General Formula (II-2) in an amount of 25 to 45%



(II-2)

(where R^5 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; R^6 represents an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 4 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 3 to 8 carbon atoms; B represents a 1,4-phenylene group or trans-1,4-cyclohexylene group which is optionally substituted with a fluorine atom; and Z^4 represents a single bond, —CH═CH—, —C≡C—, —CH_2CH_2—, —$(CH_2)_4$—, —COO—, —OCH_2—, —CH_2O—, —OCF_2—, or —CF_2O—); and

the color filter contains an organic pigment, wherein among whole particles of the organic pigment, particles having a particle size greater than 1000 nm have a volume fraction of not more than 1%, and particles having a particle size ranging from 40 nm to 1000 nm have a volume fraction of not more than 25%.

2. The liquid crystal display device according to claim 1, wherein, the particles having the particle size ranging from 40 nm to 1000 nm have a volume fraction of not more than 15%.

3. The liquid crystal display device according to claim 1, wherein the particles having the particle size ranging from 100 nm to 1000 nm have a volume fraction of not more than 7%.

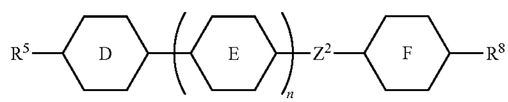
4. The liquid crystal display device according to claim 1, wherein the organic pigment has a maximum light transmittance for light having a wavelength from 600 nm to 700 nm.

5. The liquid crystal display device according to claim 1, wherein the organic pigment has a maximum light transmittance for light having a wavelength from 500 nm to 600 nm.

6. The liquid crystal display device according to claim 1, wherein the organic pigment has a maximum light transmittance for light having a wavelength from 400 nm to 500 nm.

7. The liquid crystal display device according to claim 1, wherein the organic pigment is dispersed in a coating formed on a glass substrate.

8. The liquid crystal display device according to claim 1, wherein the liquid crystal composition layer further contains a compound represented by General Formula (III) in an amount of 3 to 35%



(III)

(where R^7 and R^8 each independently represent an alkyl group having 1 to 8 carbon atoms, an alkenyl group having 2 to 8 carbon atoms, an alkoxy group having 1 to 8 carbon atoms, or an alkenyloxy group having 2 to 8 carbon atoms; D, E, and F each independently represent a 1,4-phenylene group or trans-1,4-cyclohexylene which is optionally substituted with a fluorine atom; Z^2 represents a single bond, —OCH_2—, —OCO—, —CH_2O—, or —COO—; n represents 0, 1, or 2; and the compound represented by General Formula (III) excludes the compounds represented by General Formulae (I), (II-1), and (II-2)).

9. The liquid crystal display device according to claim 1, wherein at least one compound represented by General Formula (I) in which A represents a trans-1,4-cyclohexylene group and at least one compound represented by General Formula (I) in which A represents a 1,4-phenylene group are used.

10. The liquid crystal display device according to claim **1**, wherein at least one compound represented by General Formula (II-2) in which B represents a 1,4-phenylene group and at least one compound represented by General Formula (II-2) in which B represents a trans-1,4-cyclohexylene group are used.

11. The liquid crystal display device according to claim **8**, wherein the amount of the compounds represented by General Formulae (II-1), (II-2), and (III) is in the range of 35 to 70%.

12. The liquid crystal display device according to claim **1**, wherein in the liquid crystal composition contained in the liquid crystal composition layer, Z obtained from the below equation is not more than 13000

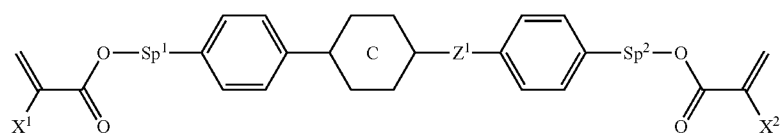
$$Z = \gamma^1 / \Delta n^2$$

(where γ1 represents rotational viscosity, and Δn represents refractive index anisotropy), γ1 is not more than 150, and Δn is in the range of 0.08 to 0.13.

13. The liquid crystal display device according to claim **1**, wherein the upper limit of a temperature of the nematic liquid crystal phase of the liquid crystal composition contained in the liquid crystal composition layer is in the range of 60 to 120° C., the lower limit is not more than −20° C., and the difference between the upper limit and the lower limit is from 100 to 150.

14. The liquid crystal display device according to claim **1**, wherein the specific resistance of the liquid crystal composition contained in the liquid crystal composition layer is not less than 10^{12} (Ω·m).

15. The liquid crystal display device according to claim **1**, wherein the liquid crystal composition layer is a polymer formed through polymerization of the liquid crystal composition further containing a polymerizable compound represented by General Formula (V)



(V)

(where X^1 and X^2 each independently represent a hydrogen atom or a methyl group; Sp^1 and Sp^2 each independently represent a single bond, an alkylene group having 1 to 8 carbon atoms, or —O—$(CH_2)_n$— (where s represents an integer from 2 to 7, and the oxygen atom is bonded to an aromatic ring); Z^1 represents —OCH_2—, —CH_2O—, —OCO—, —CH_2CH_2—, —CF_2CF_2—, —CH═CH—COO—, —CH═CH—OCO—, —COO—CH═CH—, —OCO—CH═CH—, —COO—CH_2CH_2—, —OCO—CH_2CH_2—, —CH_2CH_2—COO—, —CH_2CH_2—OCO—, —COO—CH_2—, —OCO—CH_2—, —CH_2—COO—, —CH_2—OCO—, —CY^1═CY^2— (where Y^1 and Y^2 each independently represent a fluorine atom or a hydrogen atom), —C≡C—, or a single bond; and C represents a 1,4-phenylene group, a trans-1,4-cyclohexylene group, or a single bond, and in each 1,4-phenylene group in the formula, any hydrogen atom is optionally substituted with a fluorine atom).

16. The liquid crystal display device according to claim **15**, wherein in General Formula (V), C represents a single bond, and Z^1 represents a single bond.

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